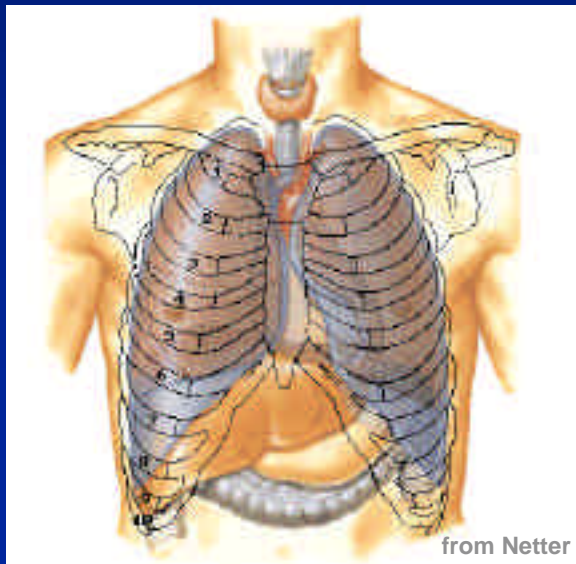


Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

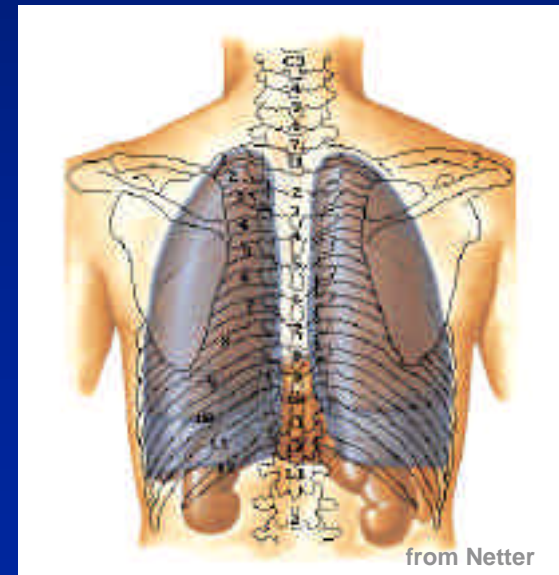
Stewart Wang, Carla Kohoyda-Inglis, June Lee,
Theresa Kennedy, Sandra Lemkin, Brian Bednarski

Lawrence W. Schneider, Joel MacWilliams,
Sheila Ebert, Chris Van Ee

The University of Michigan



CIREN Meeting
November 30, 2000
NHTSA



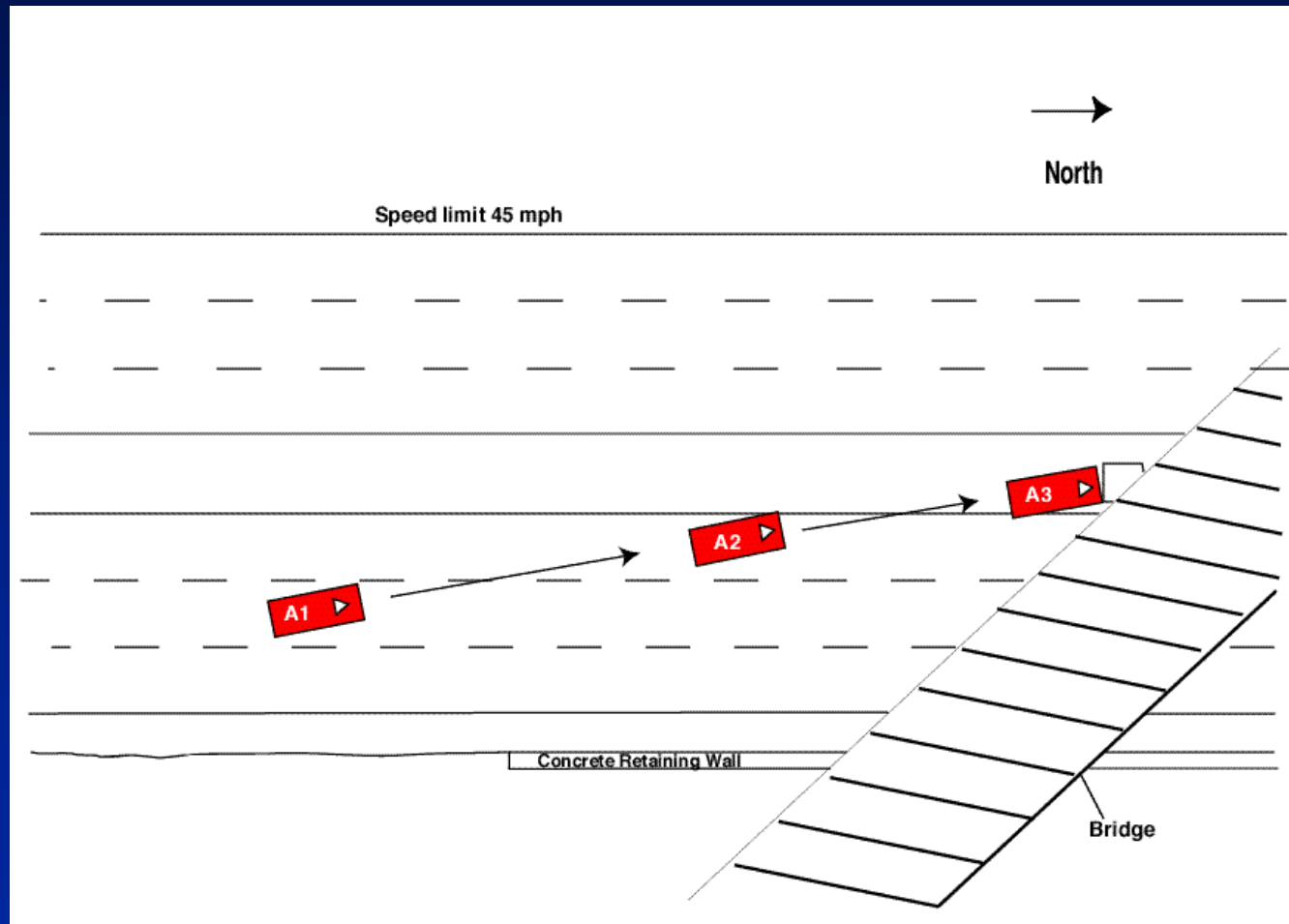
Rib Fractures and Visceral Injuries

- **July, 2000: Eppinger and Kuppa reviewed recent studies using cadavers with pressurized vascular systems in side impact crashes. Rib fractures were consistently seen, but visceral injuries were rarely observed.**
- **In real-life trauma populations, we see a high number of visceral injuries, frequently in association with rib fractures.**
- **CIREN provides detailed documentation of both rib fractures AND visceral injuries.**

Questions

- **Is there a predictive relationship between the direction and type of thorax loading and the location of rib fractures?**
- **Is there a predictive relationship between the numbers and locations of rib fractures and the extent and type of visceral injuries?**
- **How do patterns of skeletal and visceral injuries in vehicle occupants compare to those from cadaveric testing.**

Case A



Case Vehicle (RED):
2000 Buick Regal

Object struck:
concrete trestle
support

Case Occupant is
the driver and sole
occupant of the
Buick Regal

Restraint: 3-point
belt not worn,
steering-wheel
airbag deployed

Full-frontal impact;
NCAP type impact



Case A

UM CIREN



Case A

UM CIREN



Case A

UM CIREN



Case A
UM CIREN

Case A



Impact Severity: 60 mph V

PDOF: 0 degrees

Direct Damage Length: 160 cm

Maximum Crush: 108 cm

EDR record indicates:

- 3 seconds pre-impact acceleration
- no seatbelt use
- 60 mph impact speed
- no pre-impact braking

Case A



Intrusions:

Toepan
40 cm rearward

Instrument panel
10 cm rearward

Steering column
6 cm rearward



Case A



Kinematic analysis: Forward into airbag and steering wheel.

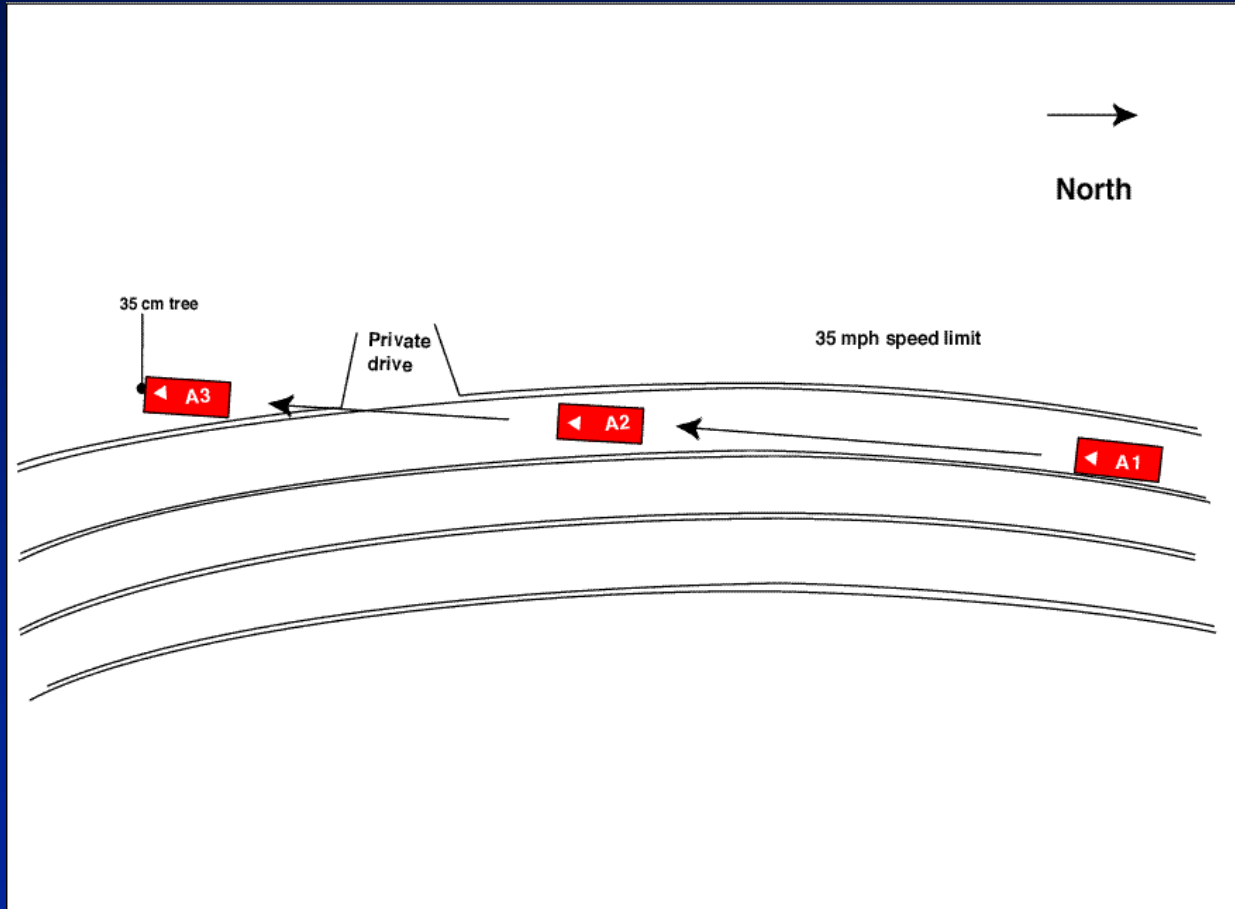
Steering-wheel rim complete collapse (11 cm on all sides)

Shear capsules with complete separation

Case A
40 y/o airbag restrained male, 183 cm, 96 kg

Injury	Contact Area	Severity
LeFort III fracture	Steering wheel hub	3
Right anterior pneumothorax	Steering wheel rim	3
Left L2-5 transverse process fractures	Non-contact (twisting mechanism)	2
Right #2-5 metatarsal fractures	Pedals and toepan	2

Case B



Case Vehicle
(RED): 1999
Plymouth Neon

Object Struck: 30
cm diameter tree

Case Occupant is
the driver and sole
occupant of the
Plymouth Neon

Restraint: 3-point
belt not worn,
steering-wheel
airbag deployed

Narrow-frontal (pole-
type) Impact

Case B



Impact Severity:
43 mph V

PDOF: 0
degrees

Direct Damage
Length: 30 cm

Maximum Crush:
153 cm

Case B



Case B



Driver Area Intrusions:

Toe pan: 96 cm rearward

Left instrument panel:
18 cm rearward

Center instrument panel:
67 cm rearward

Kinematic analysis: occupant rolls off
airbag towards right and into center stack.

Case B



Steering-wheel rim fractured, left spoke fractured, upper half and lower left portions of rim deformed (11 cm) - not extrication related

Case B

18 y/o airbag restrained female, 170 cm, 55 kg

Injury	Contact Area	Severity
Frontal contusion	Header	3
18 hour LOC	Header	4
Left pubic symphysis fracture	Center stack	3
Right open subtrochanteric femur fracture	Knee bolster and center stack	3

Case C

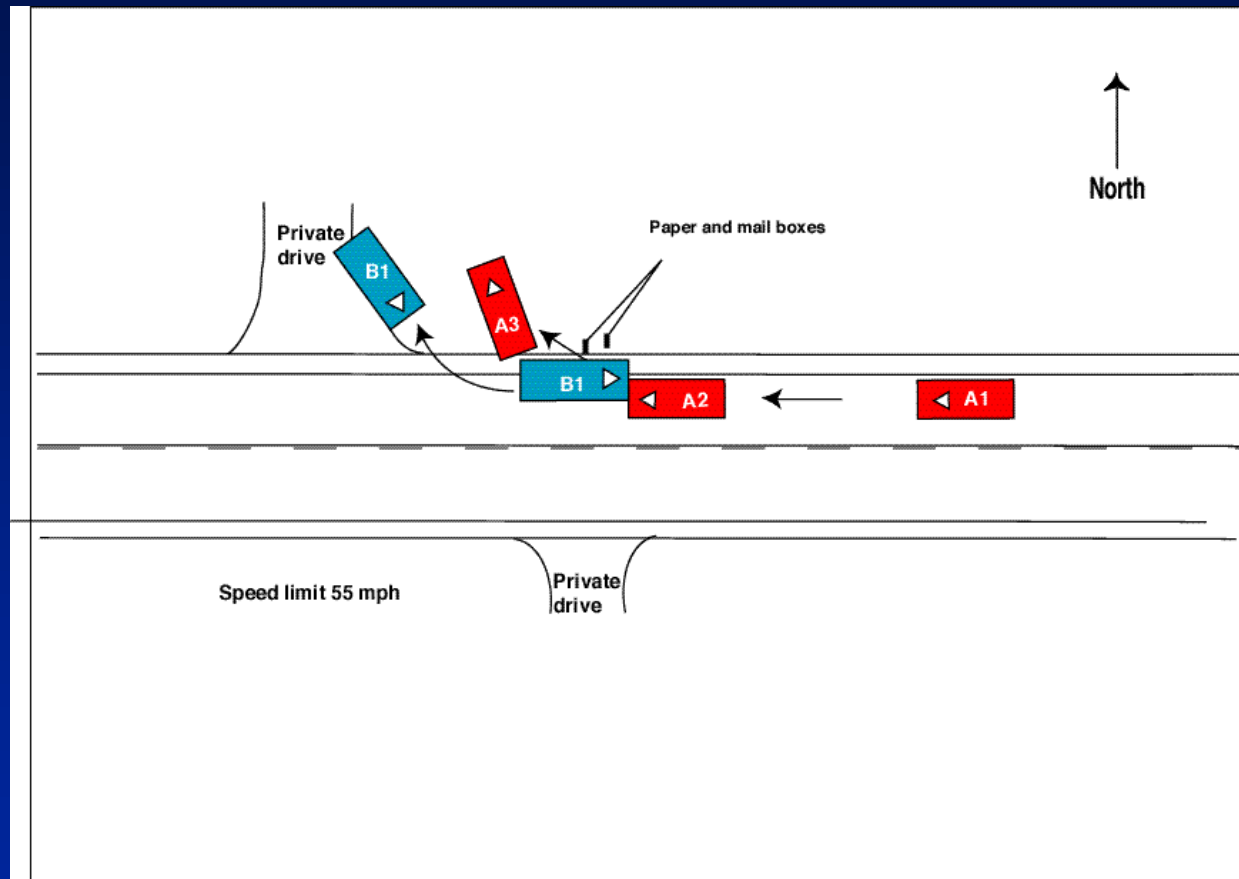
Case Vehicle (RED):
1995 Dodge Caravan

Vehicle (B): 1996
Dodge 1500 pickup -
newspaper delivery,
stopped at mailbox

Case Occupant is the
driver and sole
occupant of the Dodge
Caravan

Restraint: 3-point belt
not worn, steering-
wheel airbag deployed

Offset-frontal Impact;
75% Vehicle Overlap for
Case Vehicle



Case C



Impact Severity: 30 mph
EBS

PDOF: 0 degrees

Direct Damage Length:
123 cm

Maximum Crush: 60 cm

Case C



Case C



Driver area intrusions:

- Toepan 12 cm rearward
- Instrument panel 10 cm rearward

Case C



Upper half and right spokes of steering-wheel rim are slightly deformed (2 cm)

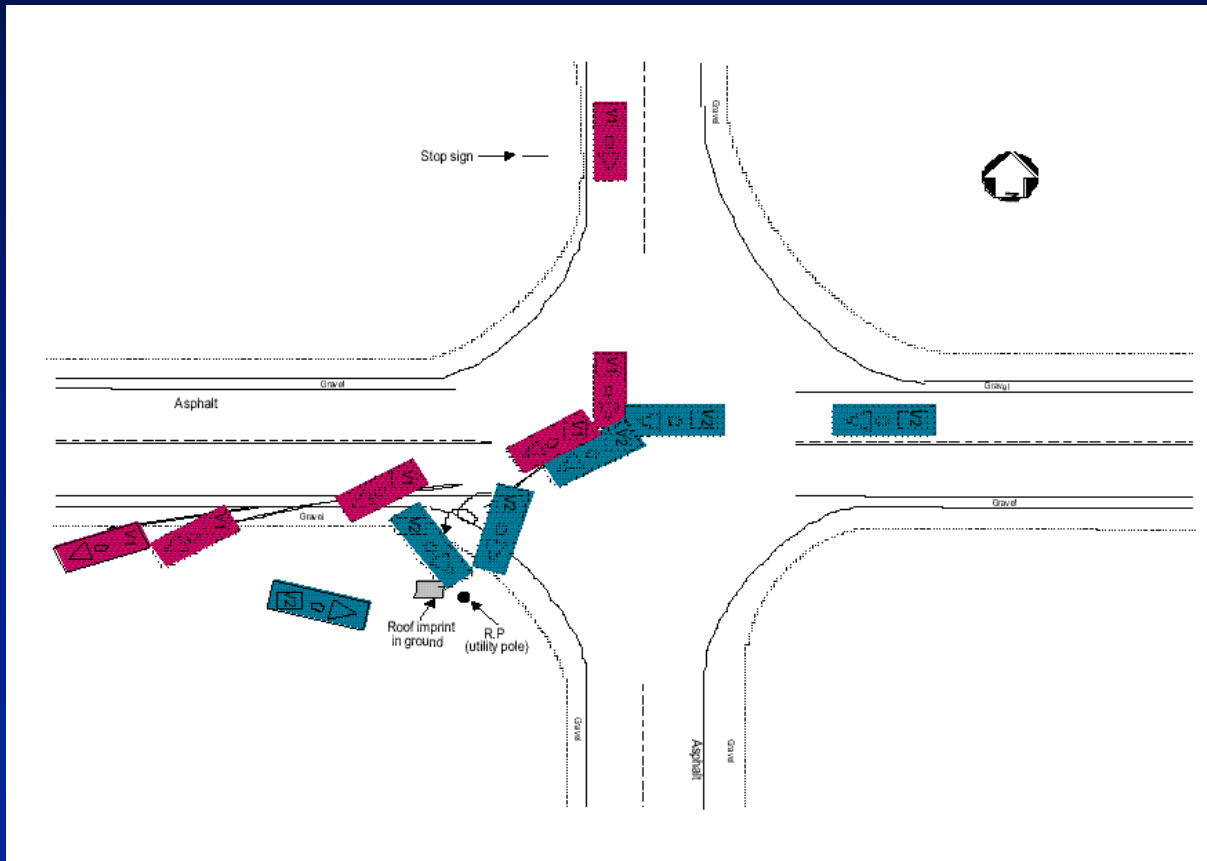
Kinematic analysis: forward (slightly right) into airbag and steering wheel

Case C

51 y/o airbag restrained male, 163 cm, 91 kg

INJURY	CONTACT AREA	SEVERITY
Right #6-9 and left 5-8 rib fractures	Airbag and Steering wheel	4
Right atrial laceration	Airbag and Steering wheel	5
Inferior vena cava laceration	Airbag and Steering wheel	3
Liver laceration	Airbag and Steering wheel	3
Splenic laceration	Airbag and Steering wheel	2

Case D



Case Vehicle (RED):
1996 Chrysler Concorde

Vehicle (B): 1999
Chevrolet 1500 pickup

Case Occupant is the
driver and sole occupant
of the Chrysler Concorde

Restraint: 3-point belt
not worn, steering-wheel
airbag deployed

Near-side impact, not
true FMVSS214 type
impact

Case D



Impact Severity: 22 mph V

PDOF: 320 degrees

Direct Damage Length: 157 cm

Maximum Crush: 64 cm

Case D



UM CIREN

Case D



Driver area intrusions:

- instrument panel 25 cm rearward
- left-front door 24 cm to right
- left kickpanel 22 cm to right
- steering column 20 cm rearward

Case D



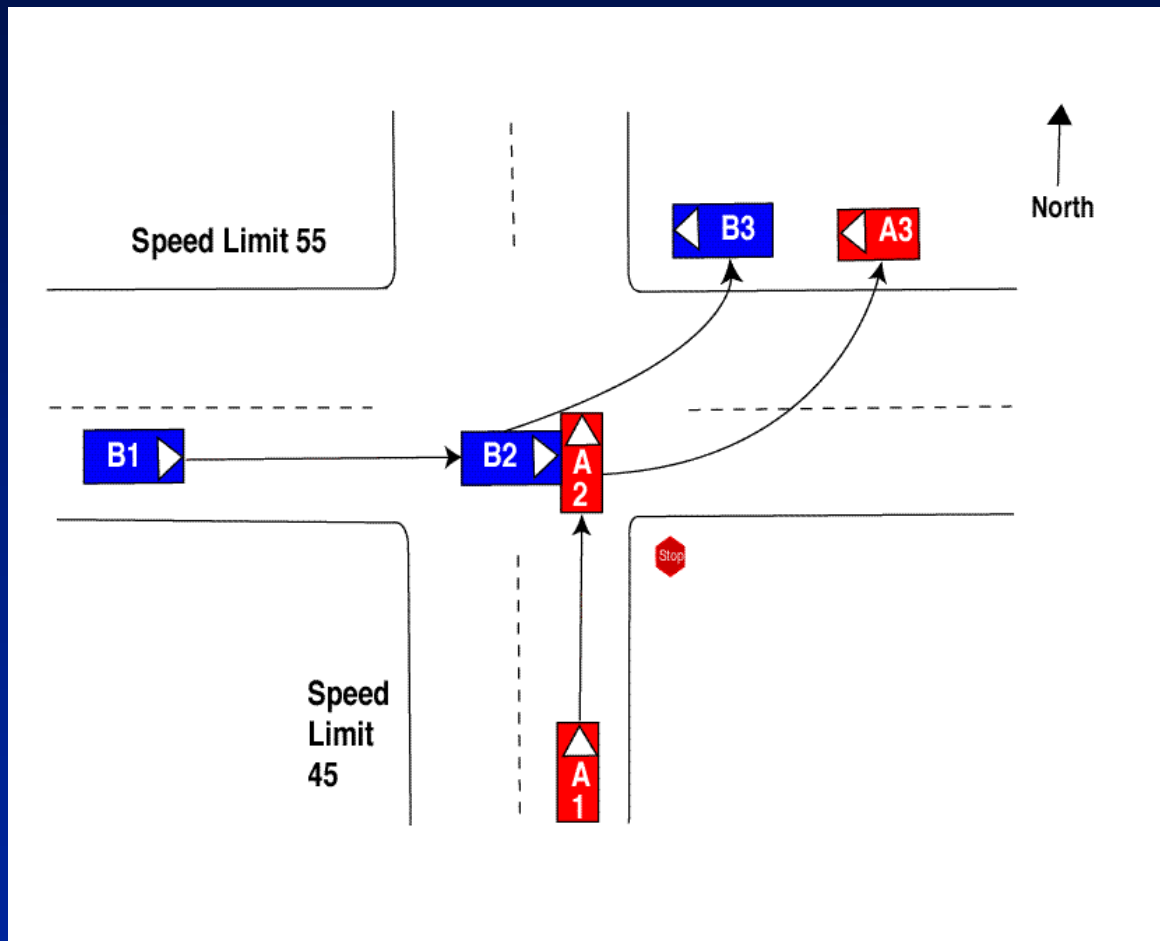
Kinematic analysis: forward off left side of airbag into A pillar and door.

Case D

79 y/o airbag restrained male, 170 cm, 74 kg

Injury	Contact Area	Severity
Bilateral temporal punctate contusions	A-pillar and windshield area	3
Left #1, 2, 6-9 rib fractures, left pulmonary contusion (flail chest)	Door	4
Right lobe liver laceration	Steering wheel	2
Left posterior acetabulum fracture	Knee bolster	3

Case E



Case Vehicle (RED):
1998 Dodge Neon

Vehicle (B): 1993
Chevrolet C2500 pickup

Case Occupant is the
driver and sole occupant
of the Dodge Neon

Restraint: 3-point belt
not worn, steering-wheel
airbag deployed

Near-side impact to an
FMVSS214 compliant
vehicle

Case E



Impact Severity: 28
mph EBS

PDOF: 290 degrees

Direct Damage
Length: 201 cm

Maximum Crush:
46 cm

Case E



Case E



Driver Area Intrusions:

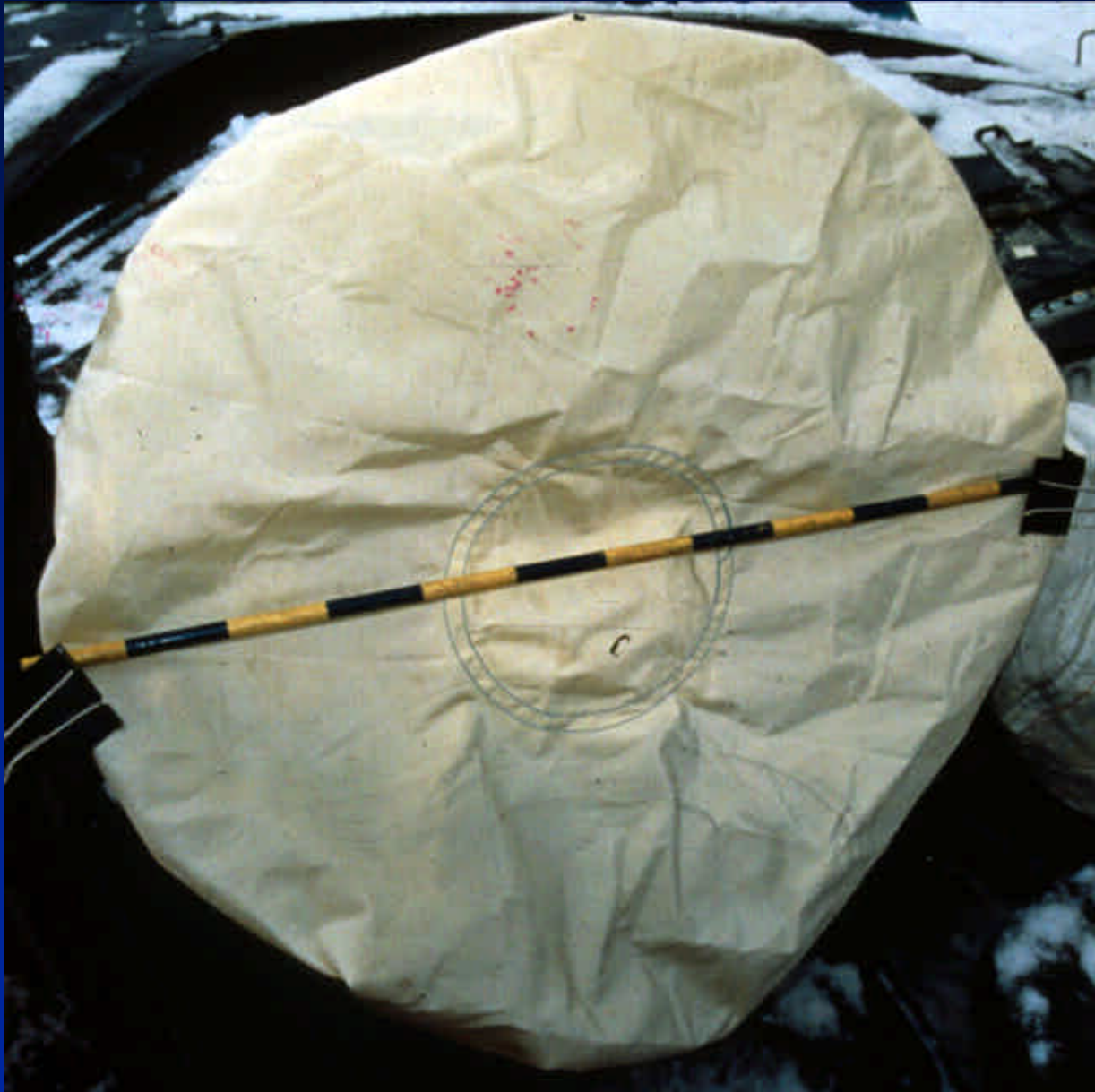
- left-front door 38
cm to right
- left B-pillar 34
cm to right
- left roof siderail
14 cm to right

Case E



Kinematic analysis: door into left side of occupant.

Case E



Restraints:

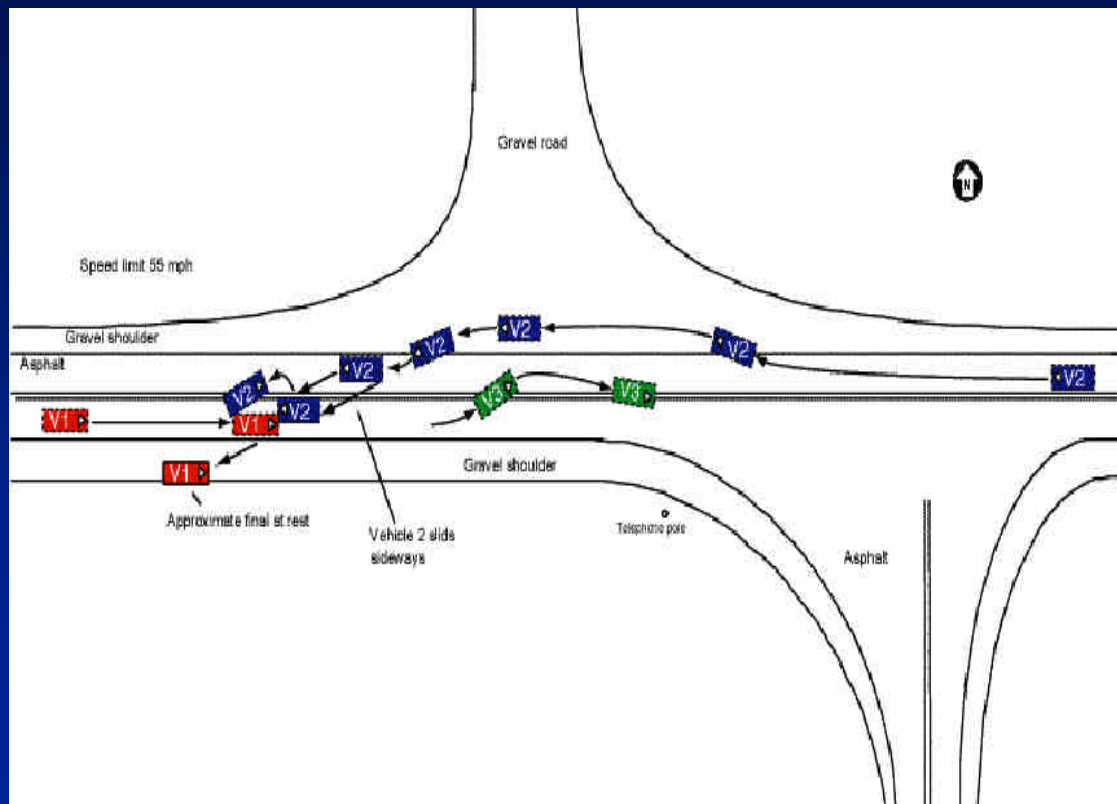
3-point belt
not worn,
steering-wheel
airbag
deployed

Case E

51 y/o airbag restrained female, 168 cm, 65 kg

Injury	Contact Area	Severity
Left #4, 5, 11 and 12 rib fractures, pneumothorax	Door	4
Complex spleen laceration	Door	5
Left superior and inferior pubic ramus fracture	Door	2
Pubic symphysis fracture	Door	3

Case F



Case Vehicle (RED): 1994 Ford Ranger

Vehicle (B): 1995 Ford Mustang

Case Occupant is the driver of the Ford Ranger

Restraint: 3-point belt worn, airbag **not** available

Angled, offset-frontal impact;
44% Vehicle Overlap

Case F



Impact Severity: 26
mph V

PDOF: 350 degrees

Direct Damage Length:
65 cm

Maximum Crush: 89 cm

Case F



Driver Area Intrusions:

- toepan 38 cm rearward
- instrument panel 37 cm rearward
- kickpanel 15 cm to right

Case F



Steering Column separated
from shear capsules

Upper-half of steering-
wheel rim deformed (6 cm)

Case F



Kinematic analysis: forward and to left of steering wheel. Chest pined between steering wheel and intruding door.

Case F

53 y/o 3-point-belt restrained female, 178 cm 82 kg

Injury	Contact Area	Severity
Right intraventricular hemorrhage	Steering wheel rim	4
Right #1 and 4 and left 6-8 rib fractures, bilateral pneumothoraces	Steering wheel (R ribs) Door (L ribs)	4
Left diaphragm laceration	Steering wheel	3
Right humerus fracture	Steering wheel rim	3
Right anterior column acetabular fracture	Knee bolster	3

Take home points

- **Airbags can provide very good protection of the chest in frontal crashes.**
- **Rib fractures and visceral injuries are both frequently observed in real-life crashes, often concurrently.**
- **The anatomic detail provided by CT imaging provides insight into the relationship between specific rib fractures and visceral injuries as well as the mechanism of injury causation.**

**Analysis of UofM CIREN
Crash/Injury Database re
Patterns of Skeletal and Visceral
Thorax/Abdomen Injuries in
Frontal and Near-Side Impacts**

Analysis of UofM CIREN Crash/Injury Database re Patterns of Skeletal and Visceral Thorax/Abdomen Injuries in Frontal and Near-Side Impacts

CIREN offers a new and unique opportunity to examine the specific spatial relationships of skeletal and visceral injuries to the thorax/abdomen of real-life crash victims for different crash, restraint, and occupant conditions.

Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

The results of this analysis can:

- help validate or interpret cadaver test data used to develop thoracic injury criteria,
- help determine injury causation in real-world crashes, and
- provide clues to visceral injuries in trauma patients.

Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

Overview of Analysis to Date

- **Injured and not-injured populations - key variables**
- **Injured Population**
 - **Frequencies of skeletal and visceral injuries**
 - **Locations of rib fractures by impact type and restraint**
 - **Relationships between skeletal and visceral Injuries**
- **Observations from analysis to date**
- **Recommendations**

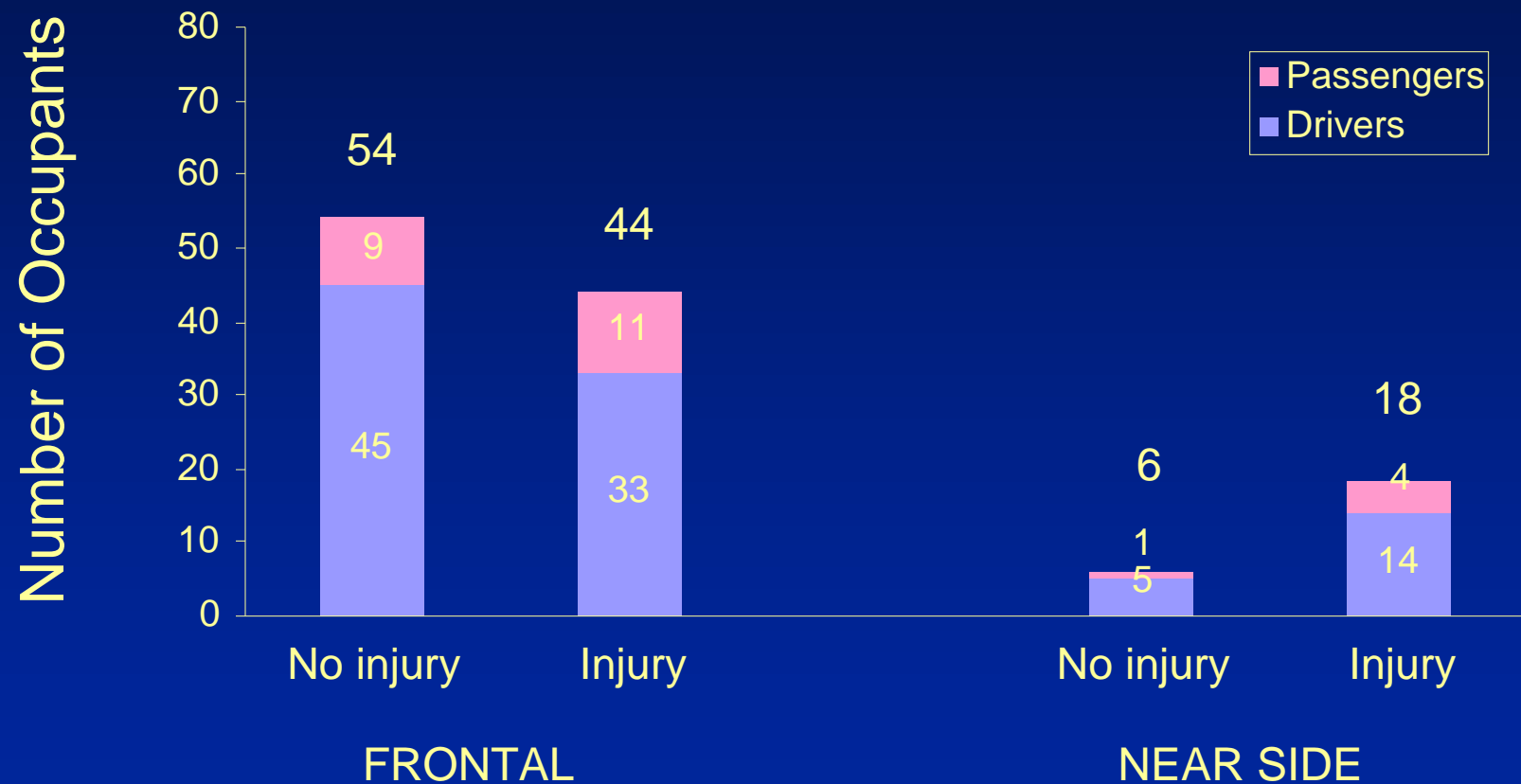
**Analysis of UofM CIREN Database re
Patterns of Skeletal and Visceral Injuries in
Frontal and Near-Side Impacts**

Work in Progress

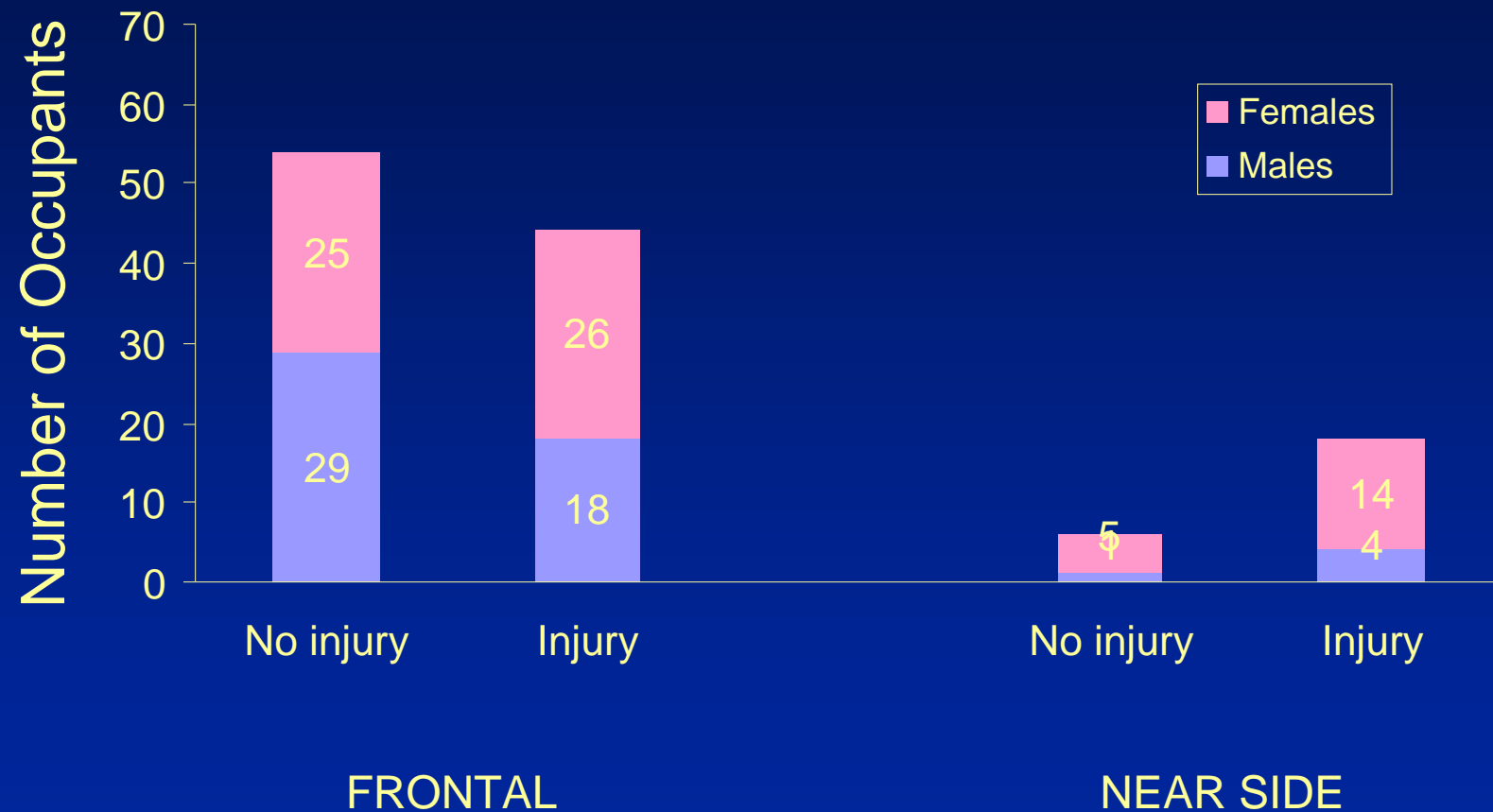
Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

**Injury and No-Injury Cases
(Injury = AIS < 2)**

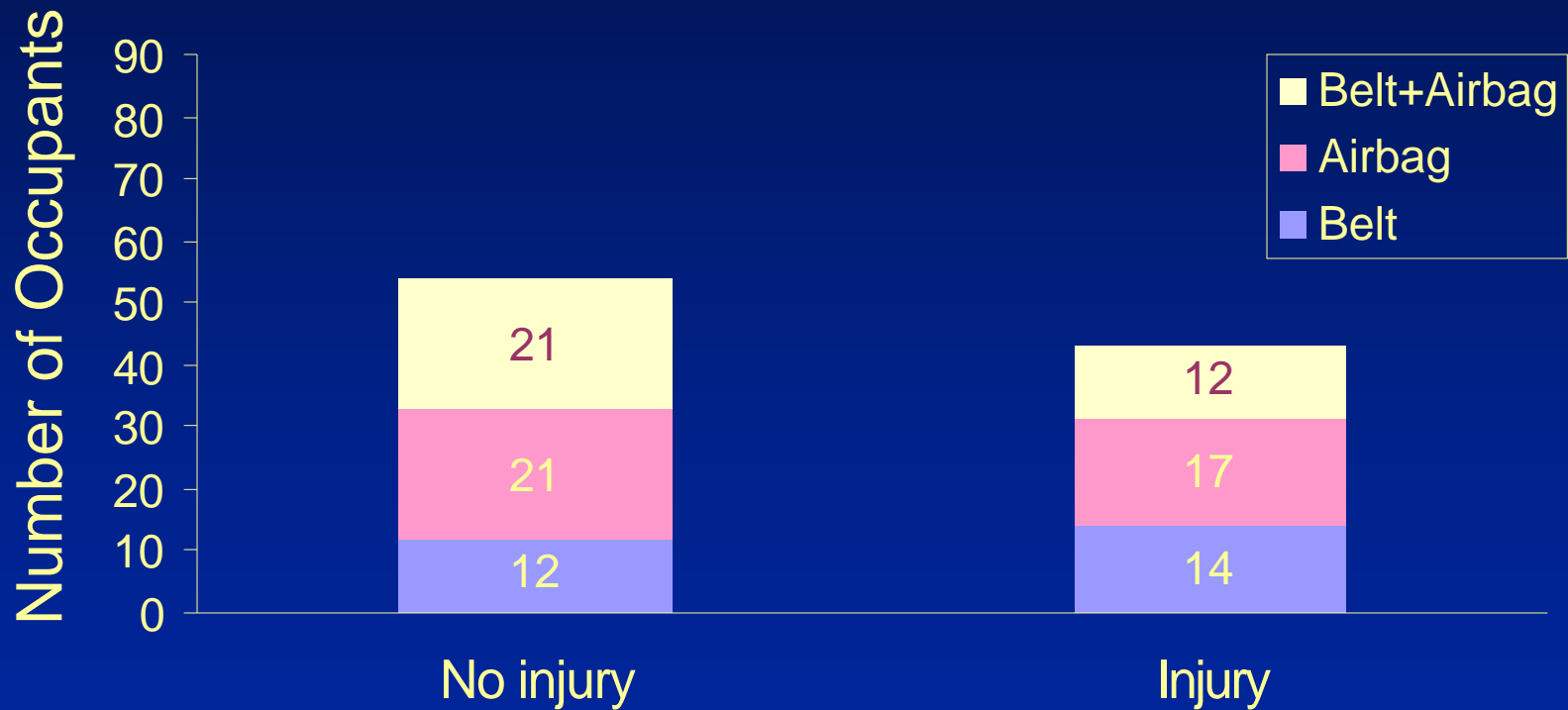
Occupant Position for Injury and No-Injury Cases



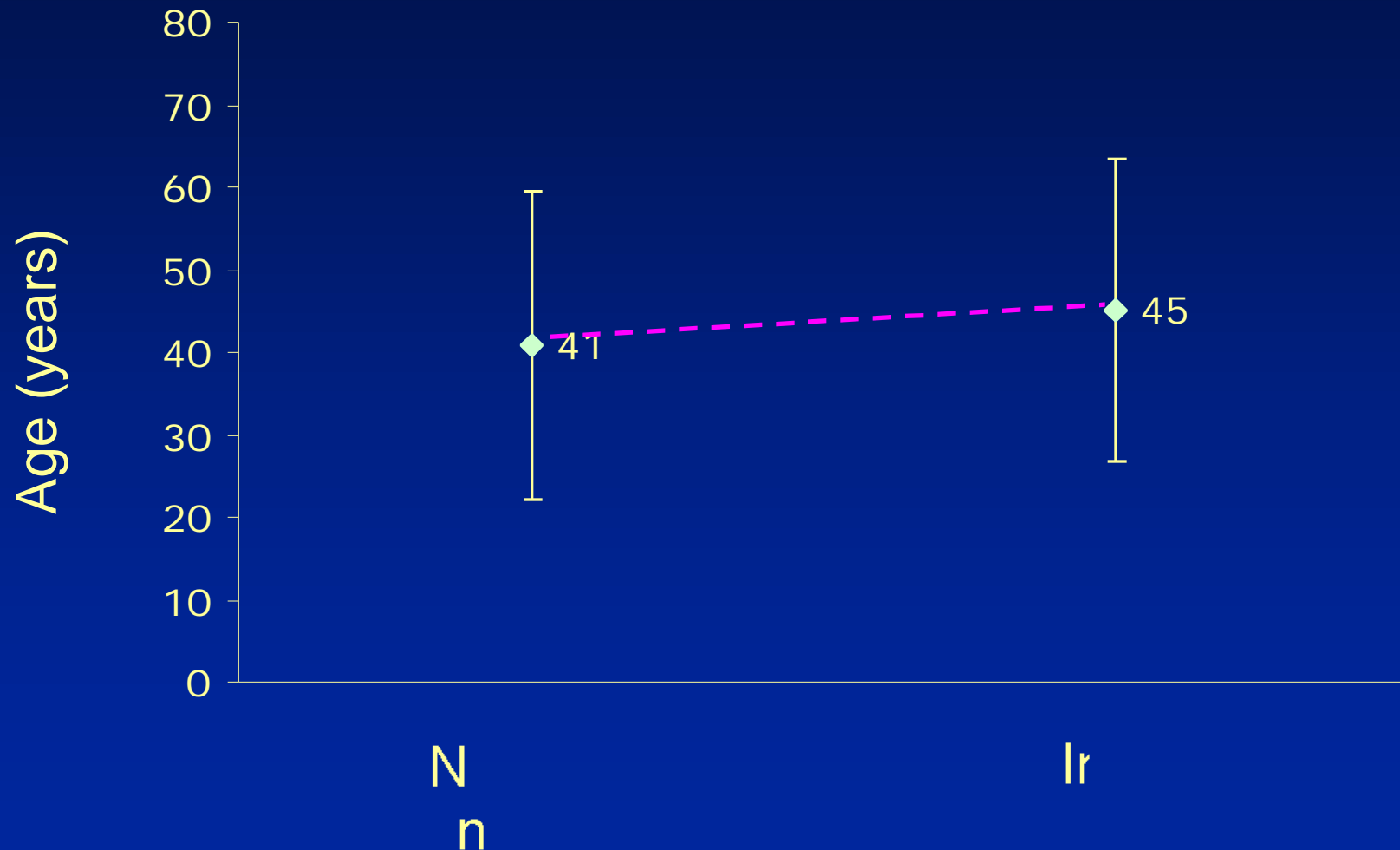
Occupant Gender for Injury and No-Injury Cases



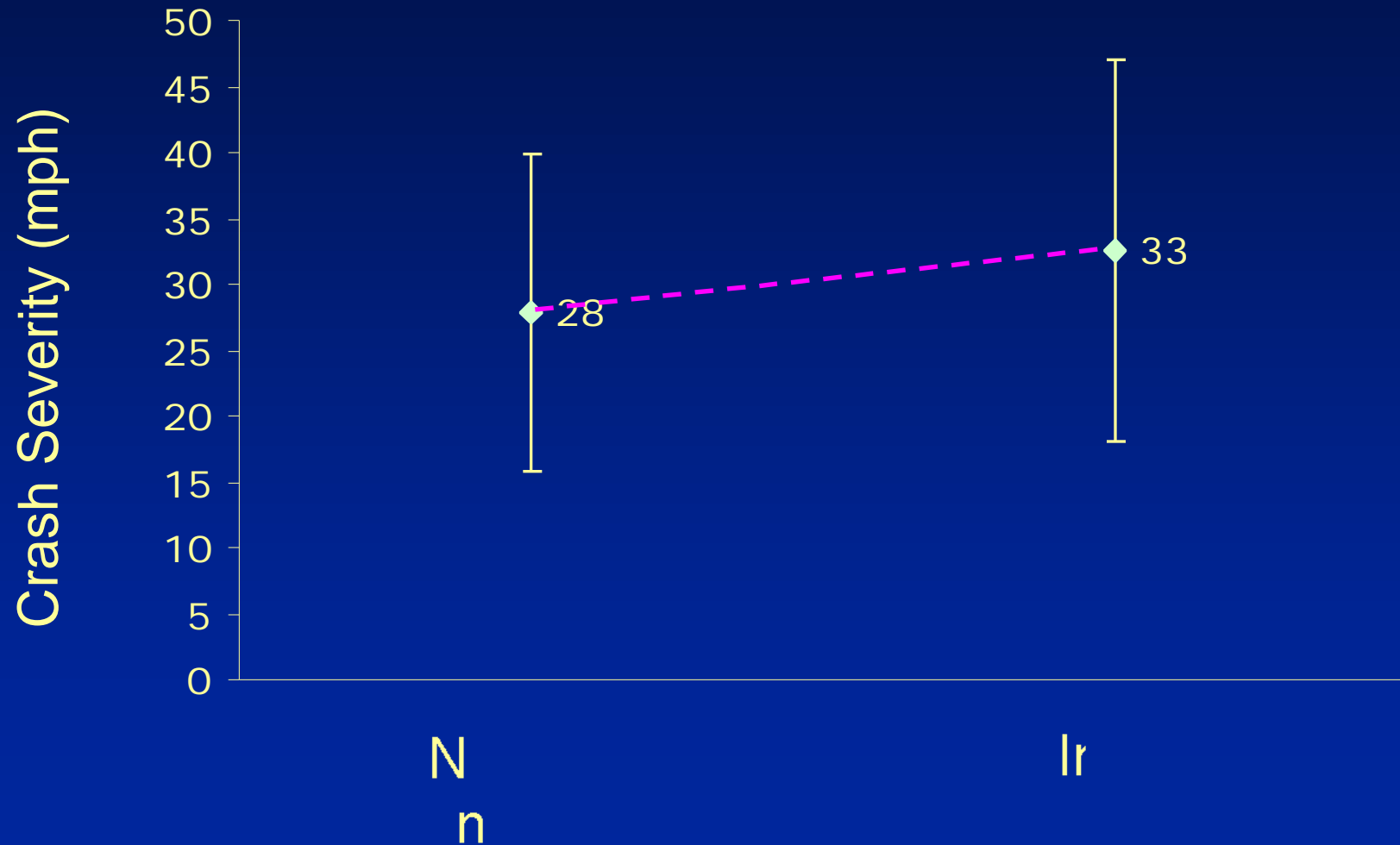
Restraint Usage for Injury and No-Injury Cases in FRONTAL Impacts



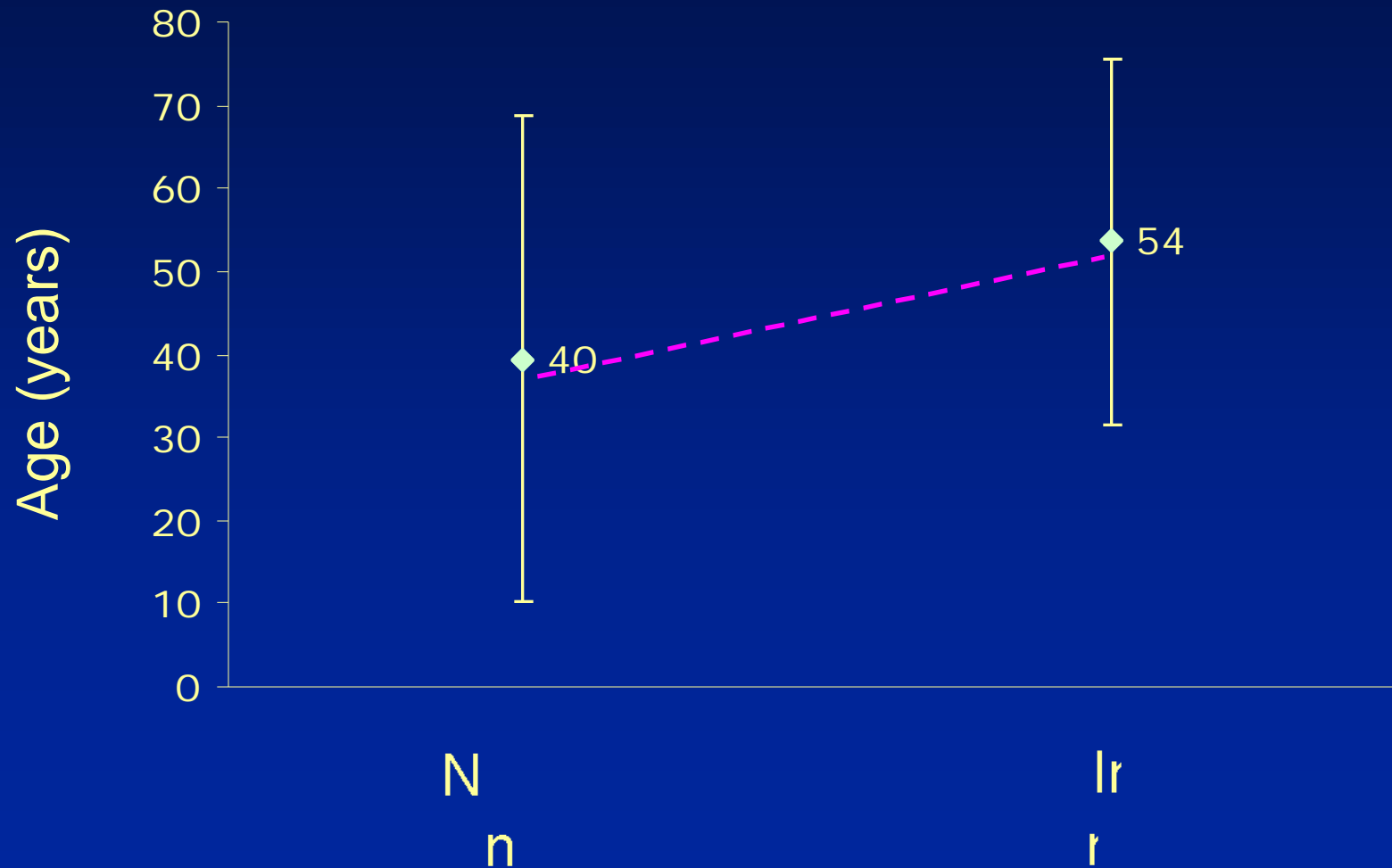
Age of Occupants in FRONTAL Impacts



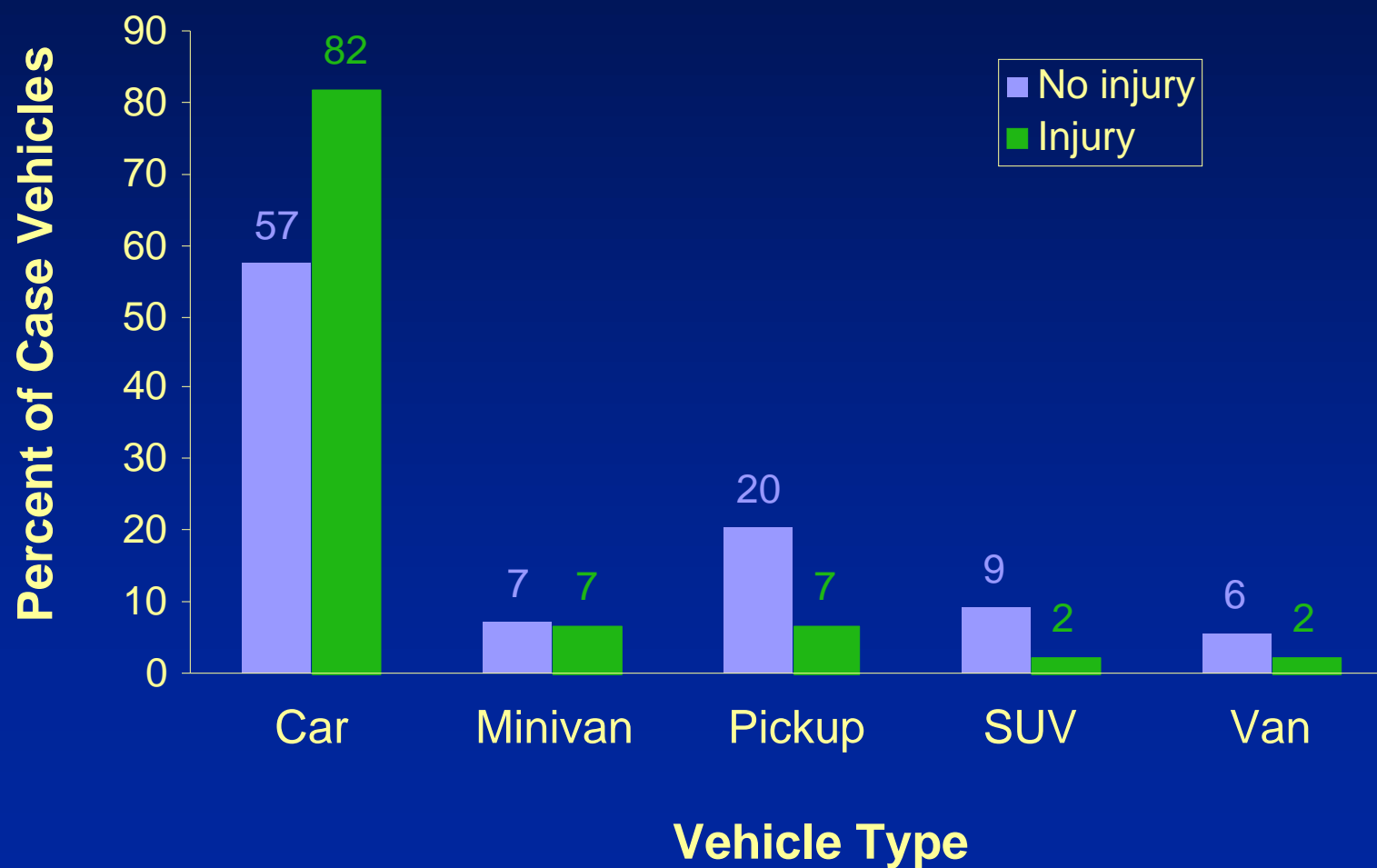
Crash Severity in **FRONTAL** Impacts



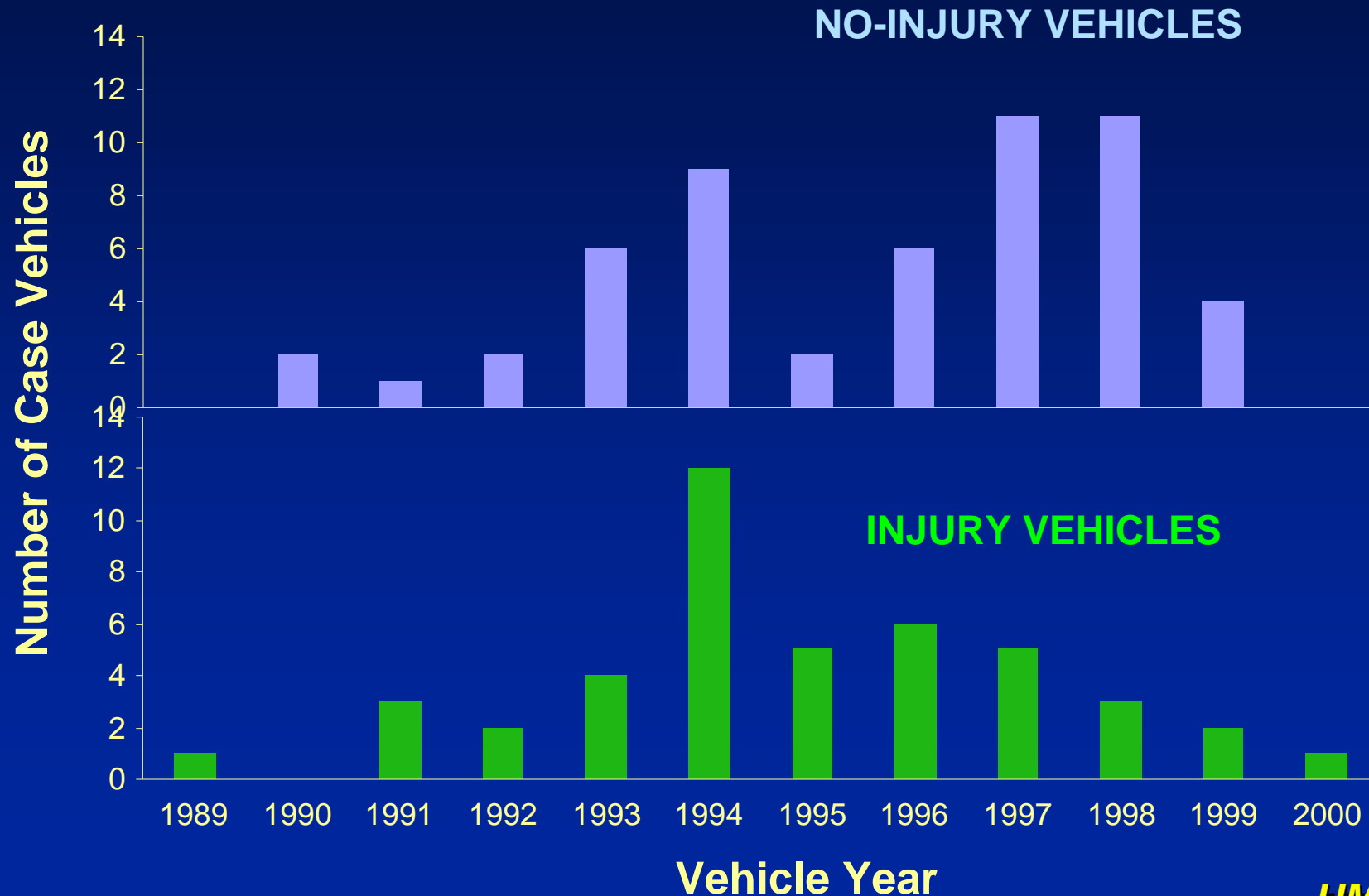
Age of Occupants in NEAR-SIDE Impacts



Vehicle Type as Percent of Injury and No-Injury Cases in FRONTAL Crashes



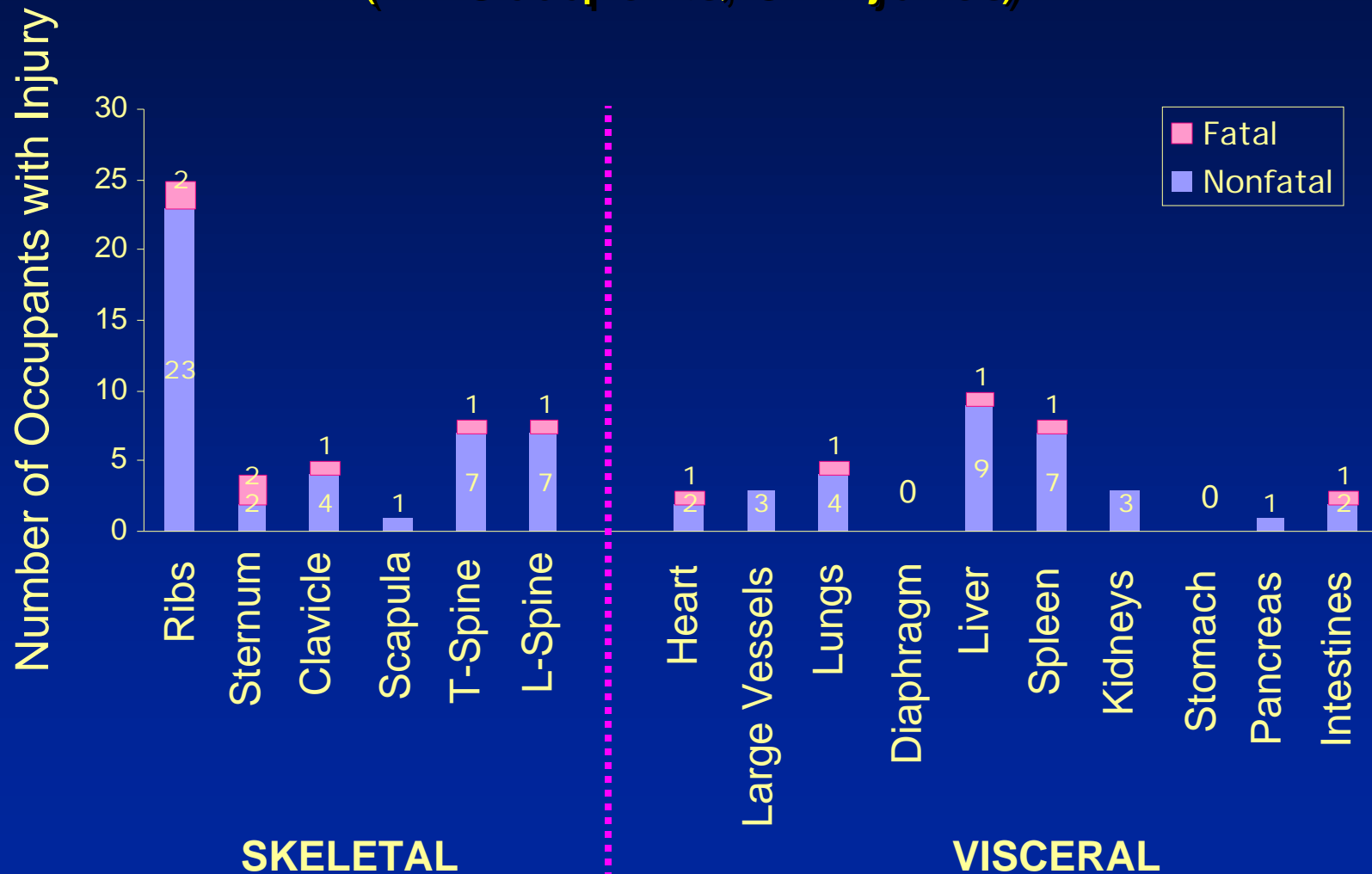
Vehicle Model Year for Injury and No-Injury FRONTAL Crashes



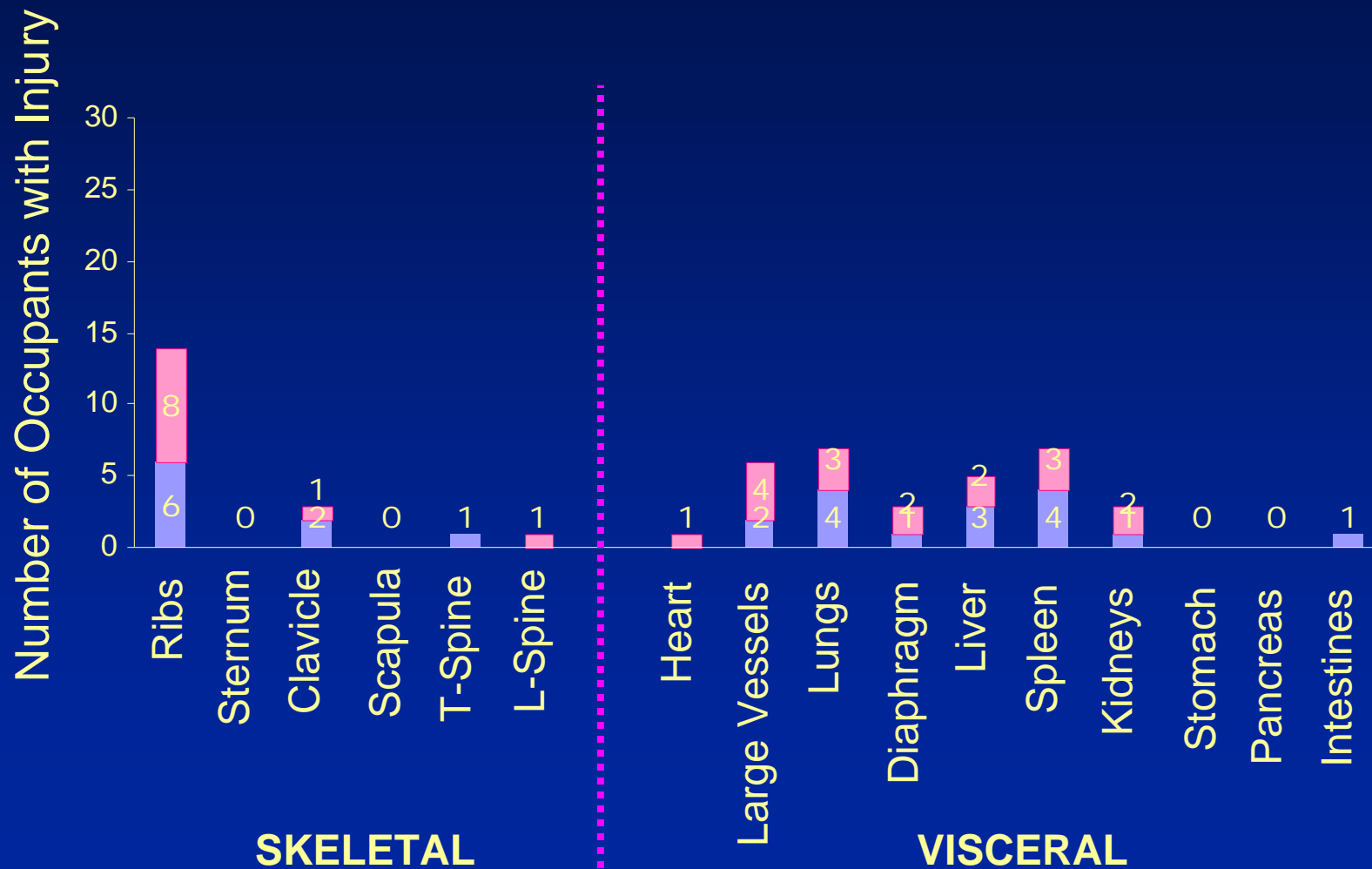
Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

Overview of Skeletal and Visceral Thorax/Abdomen Injuries in UofM CIREN Database

Count of Occupants with Different AIS \geq 2 Skeletal and Visceral Injuries in FRONTAL Impacts (44 Occupants, 87 Injuries)

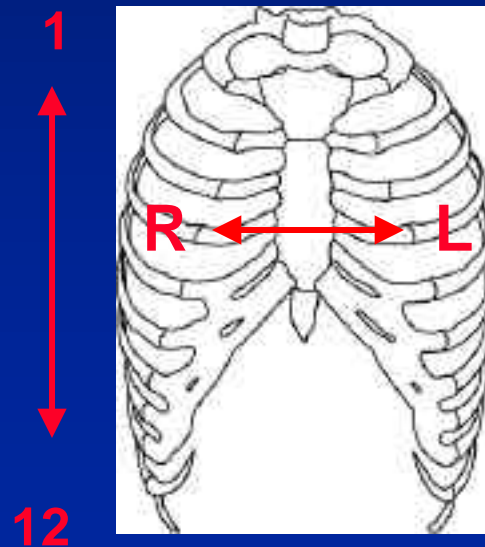


Count of Occupants with
Different AIS ≥ 2 Skeletal and Visceral Injuries
in NEAR SIDE Impacts
(18 Occupants, 52 Injuries)

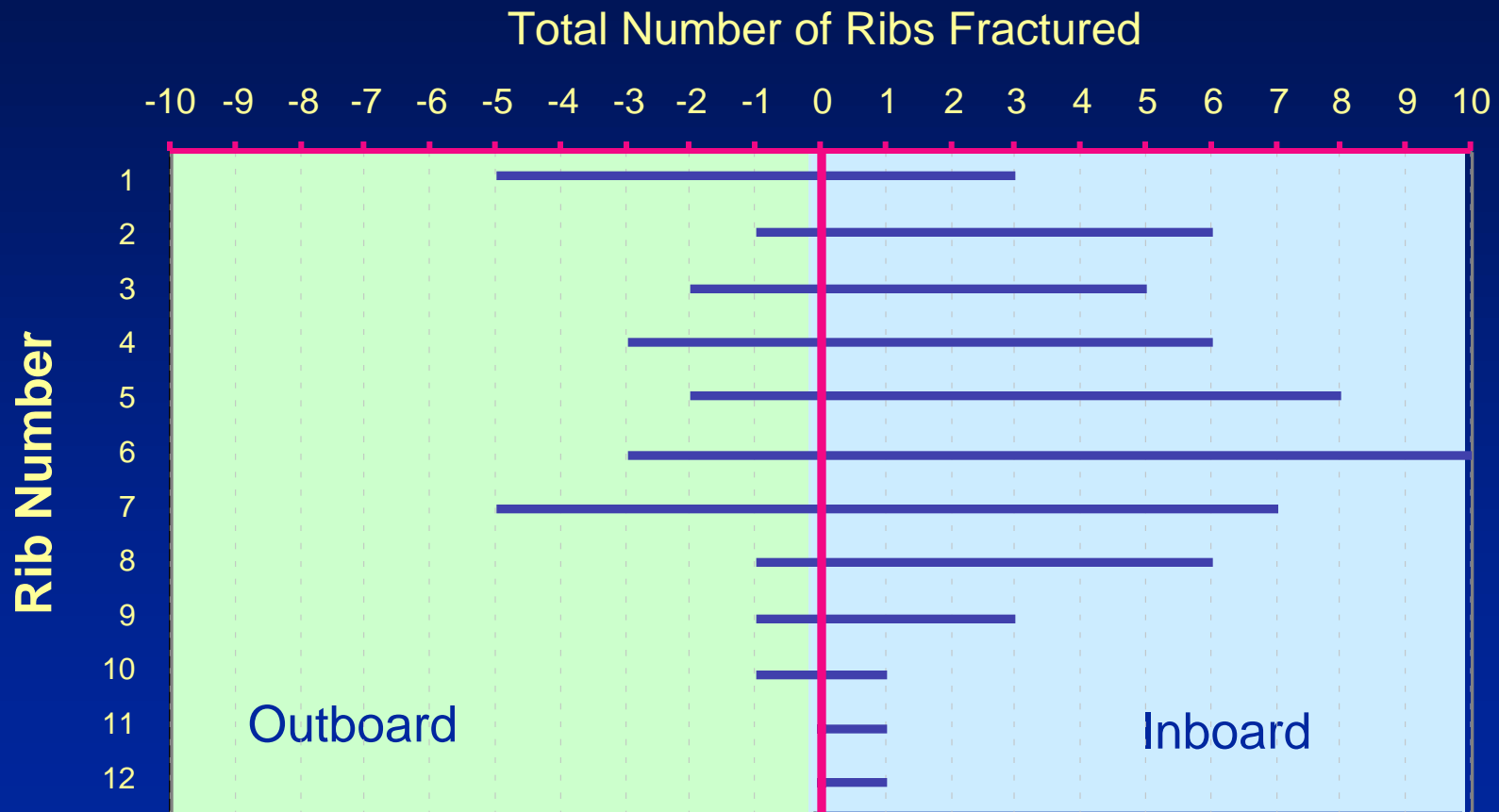


Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

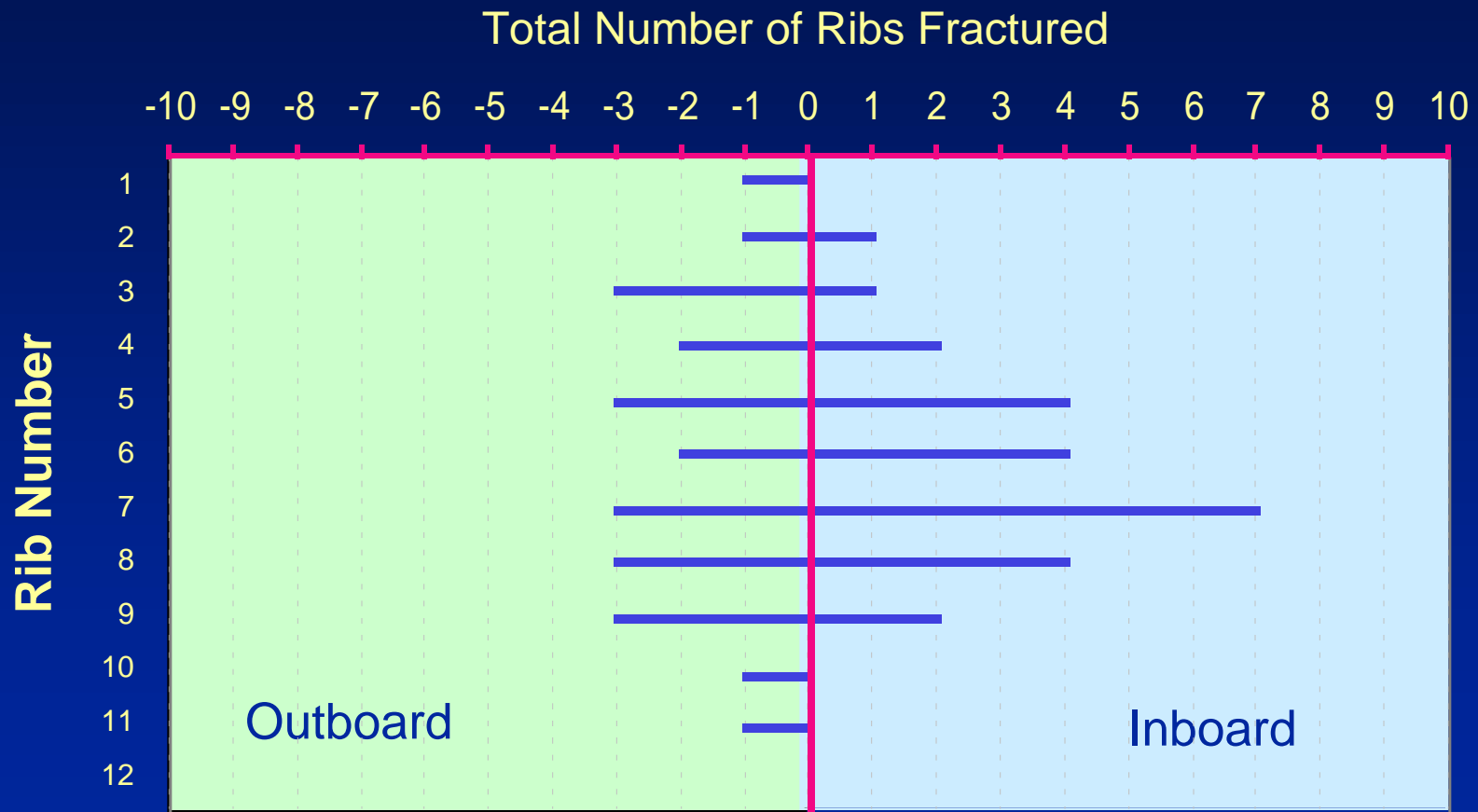
Locations of Rib Fractures by Rib # and Side



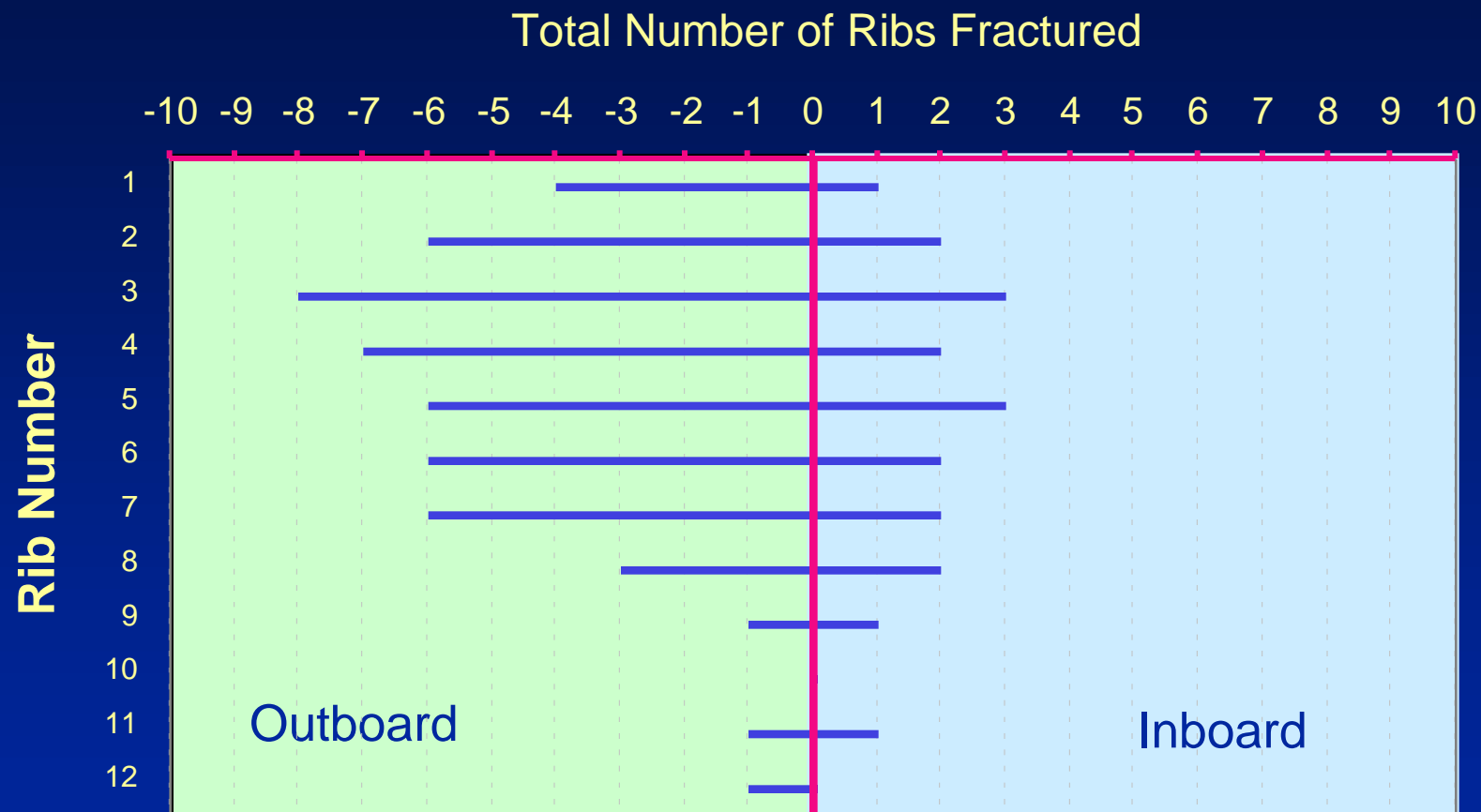
19 Occupants with Belt Restraint, With and Without Airbag in FRONTAL Crashes



10 Occupants with Airbag Only in FRONTAL Crashes

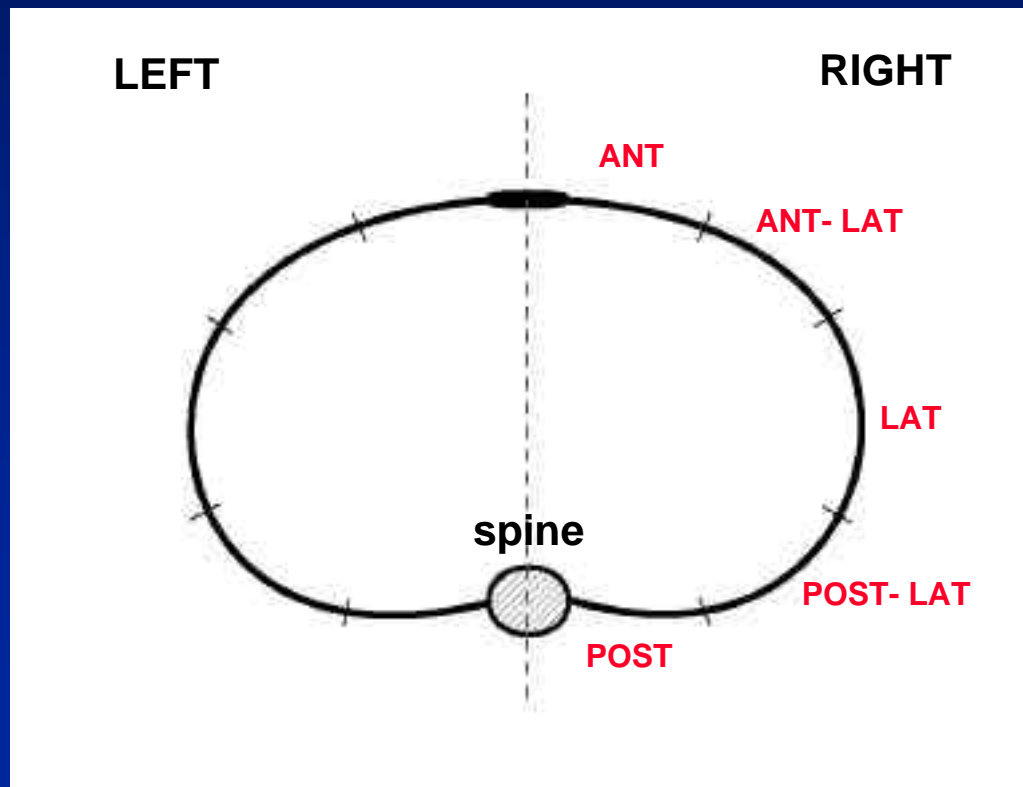


13 Occupants in NEAR-SIDE Crashes

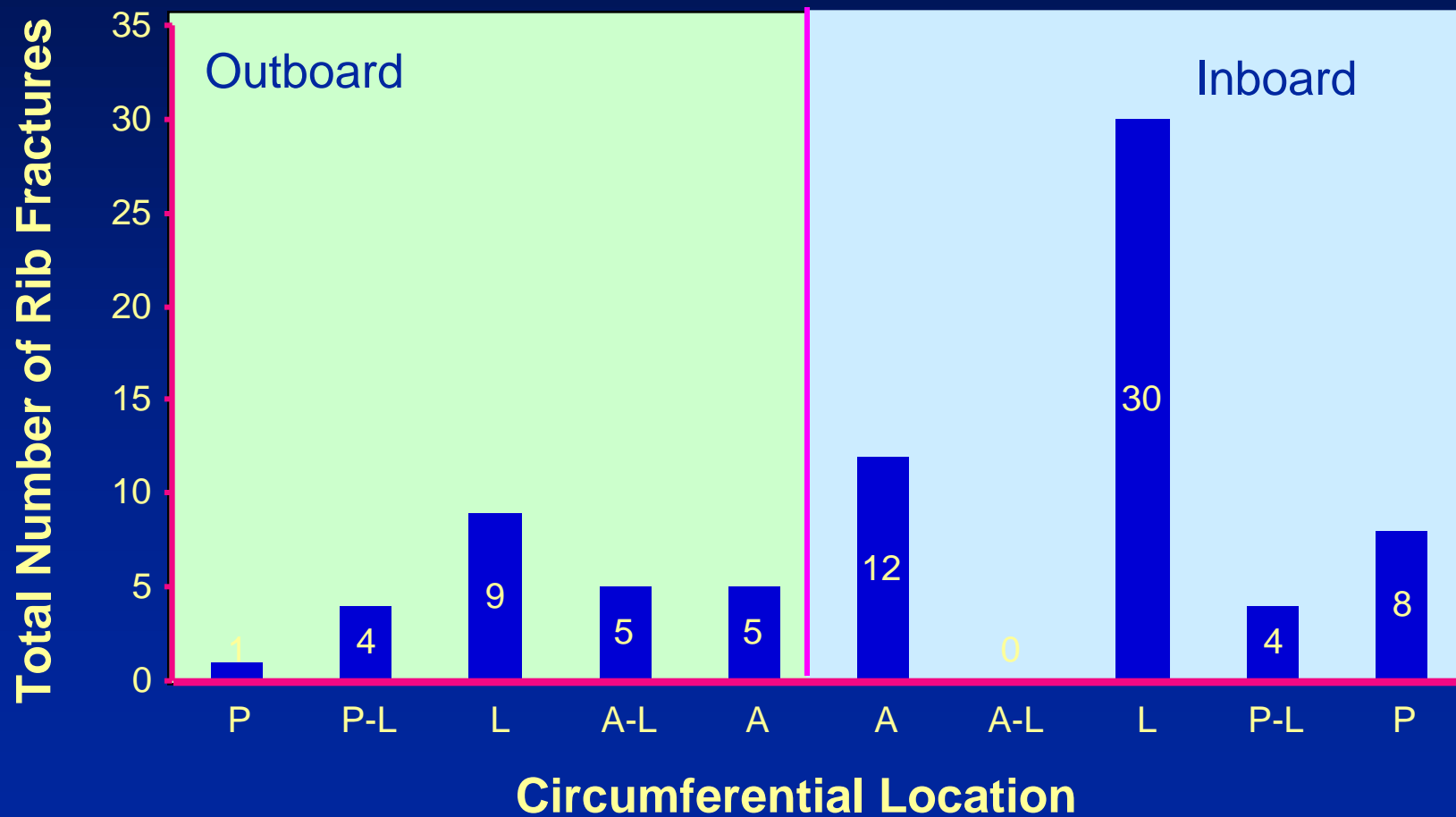


Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

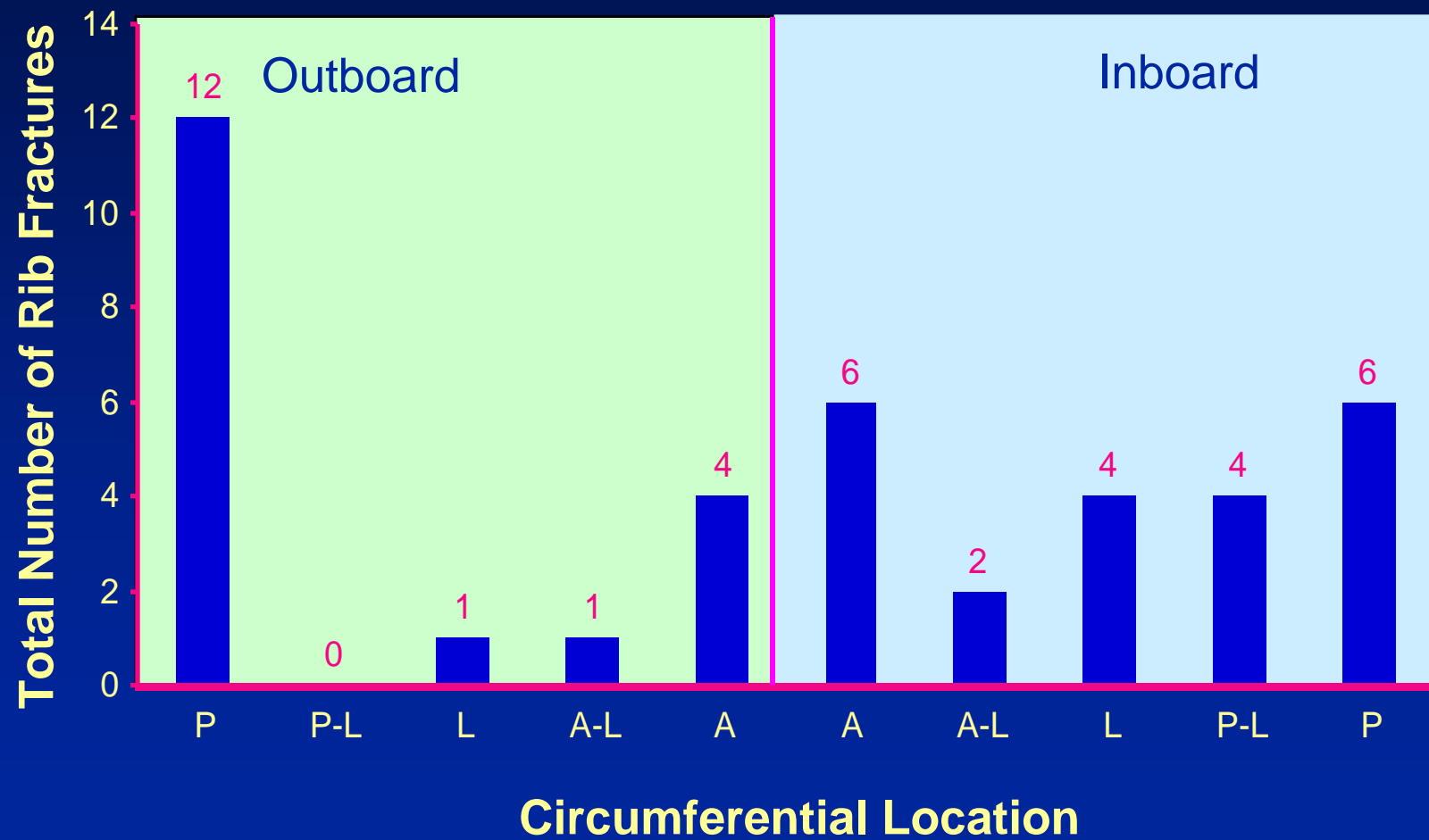
Circumferential Locations of Rib Fractures



19 Belt-Restrained Occupants, With or Without Airbag in FRONTAL Crashes



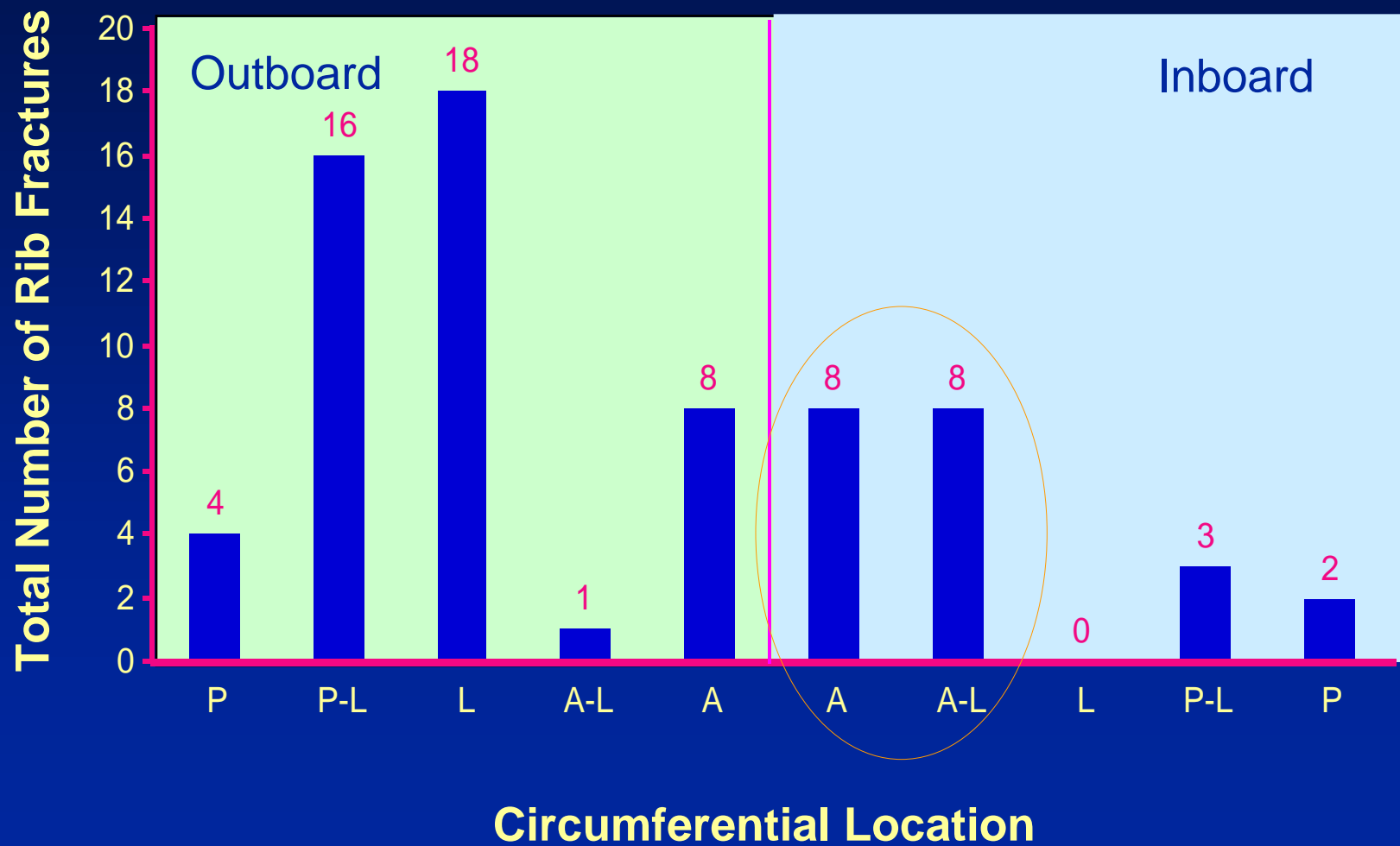
10 Occupants With Airbag Only in FRONTAL Crashes



Sources of Thorax/Abdomen Injuries for Airbag-Only Restrained Occupants in FRONTAL Crashes

Instrument panel	7
Steering wheel	6
Center stack	2
Door	3

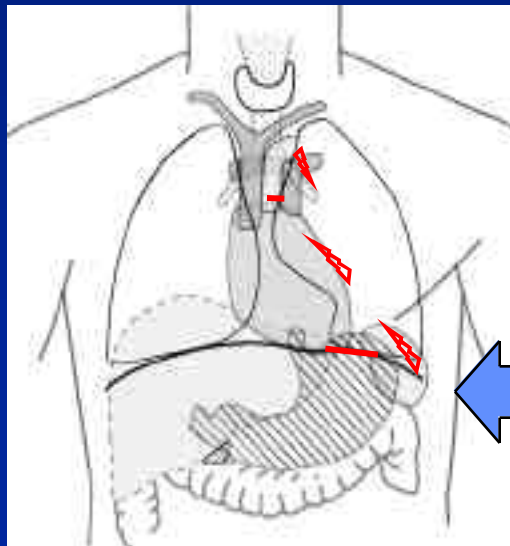
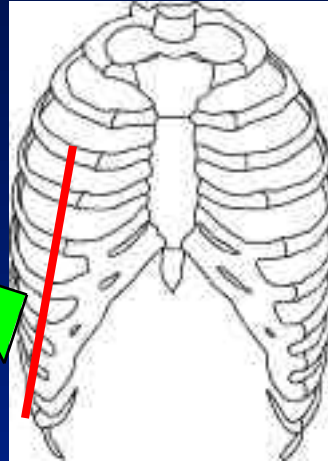
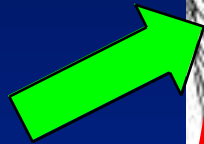
13 Occupants with Airbag Only in NEAR-SIDE Impacts



Patterns of Skeletal and Visceral Injuries to Two Elderly Female Belt-Restrained Drivers in NEAR-SIDE Impacts

Anterior and ant-lat rib fractures #2-9

Belt loading



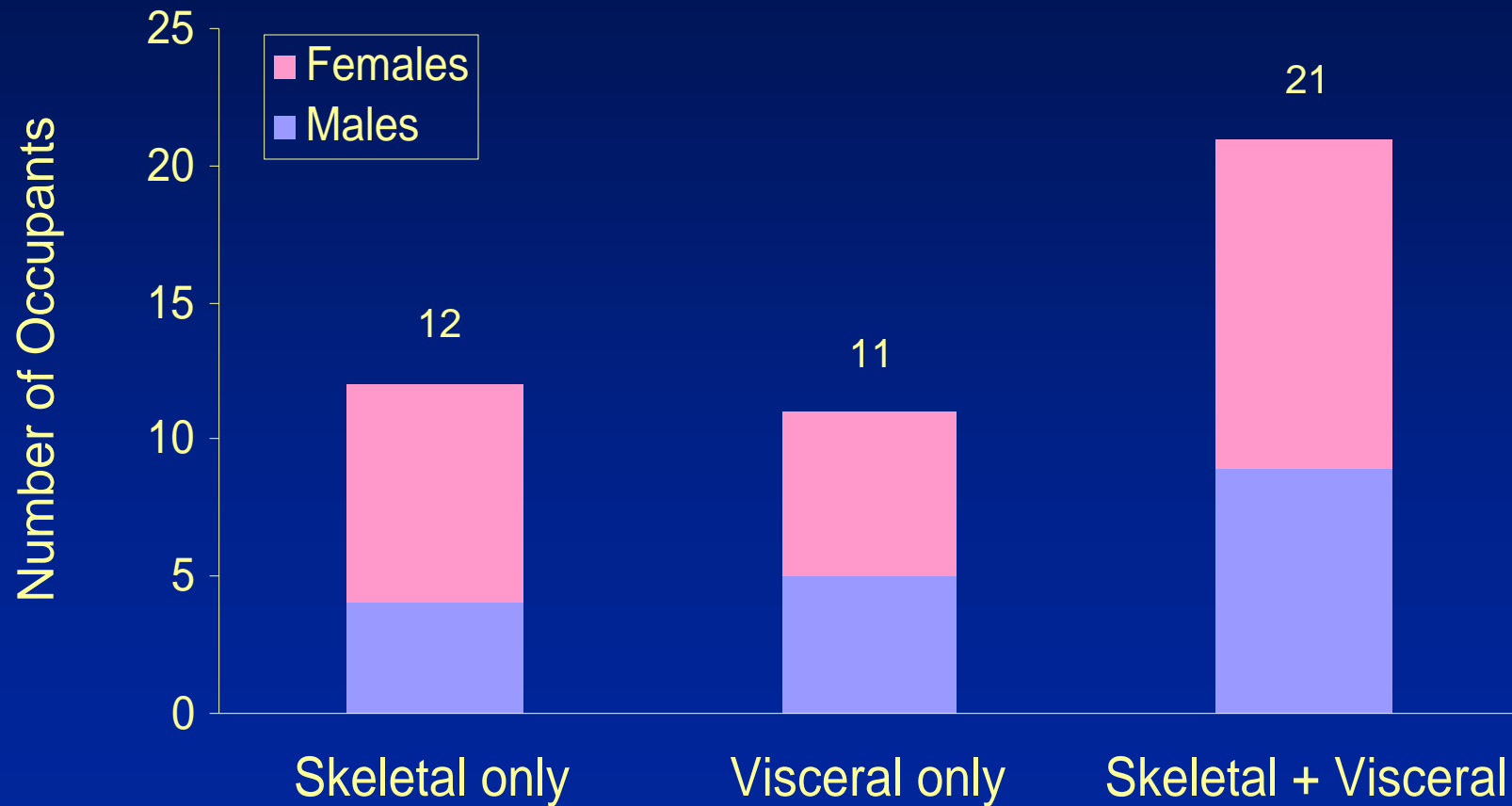
Door loading

- Left pericardium tear
- Posterior ascending aortic dissection
- Left posterior diaphragm laceration
- Grade II spleen laceration
- Left pulmonary artery laceration

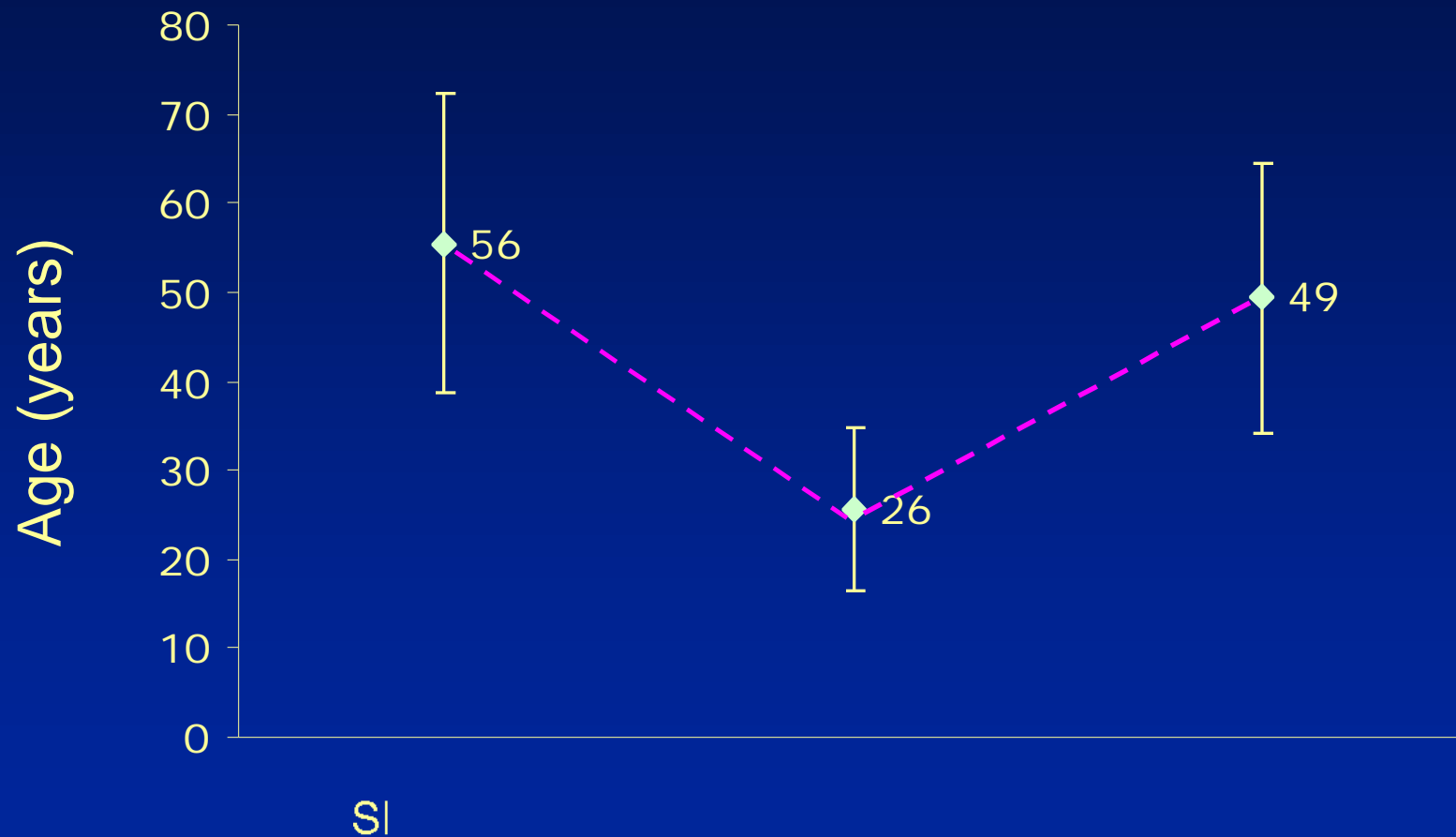
Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

Occupants with
Skeletal Only (S),
Visceral Only (V),
and
Skeletal+Visceral (S+V)

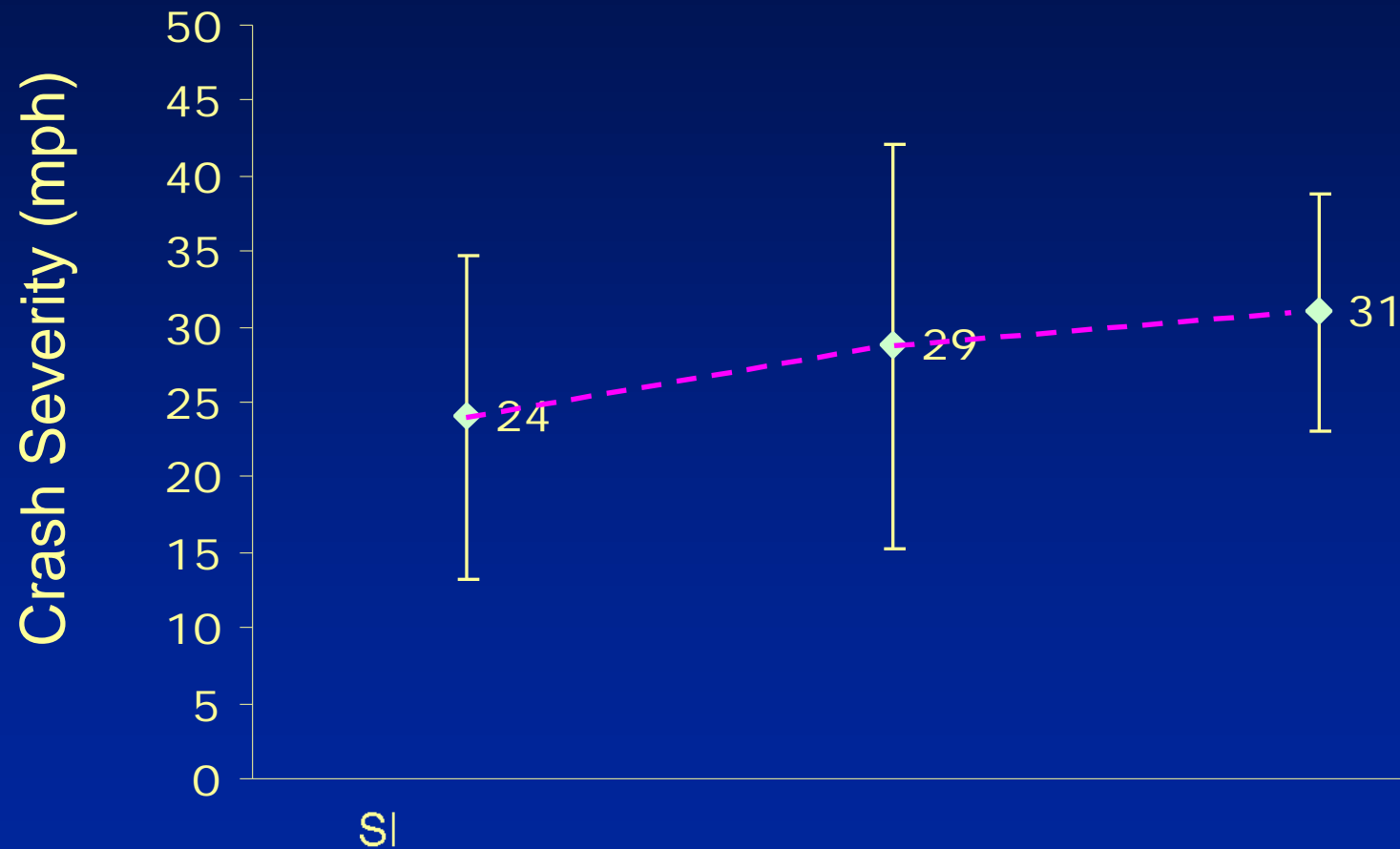
Occupants With S, V, and S+V Injuries in FRONTAL Impacts



Age of Occupantgs With S, V, and S+V Injuries in FRONTAL Impacts



Crash Severity for S, V, and S+V Cases in FRONTAL Impacts



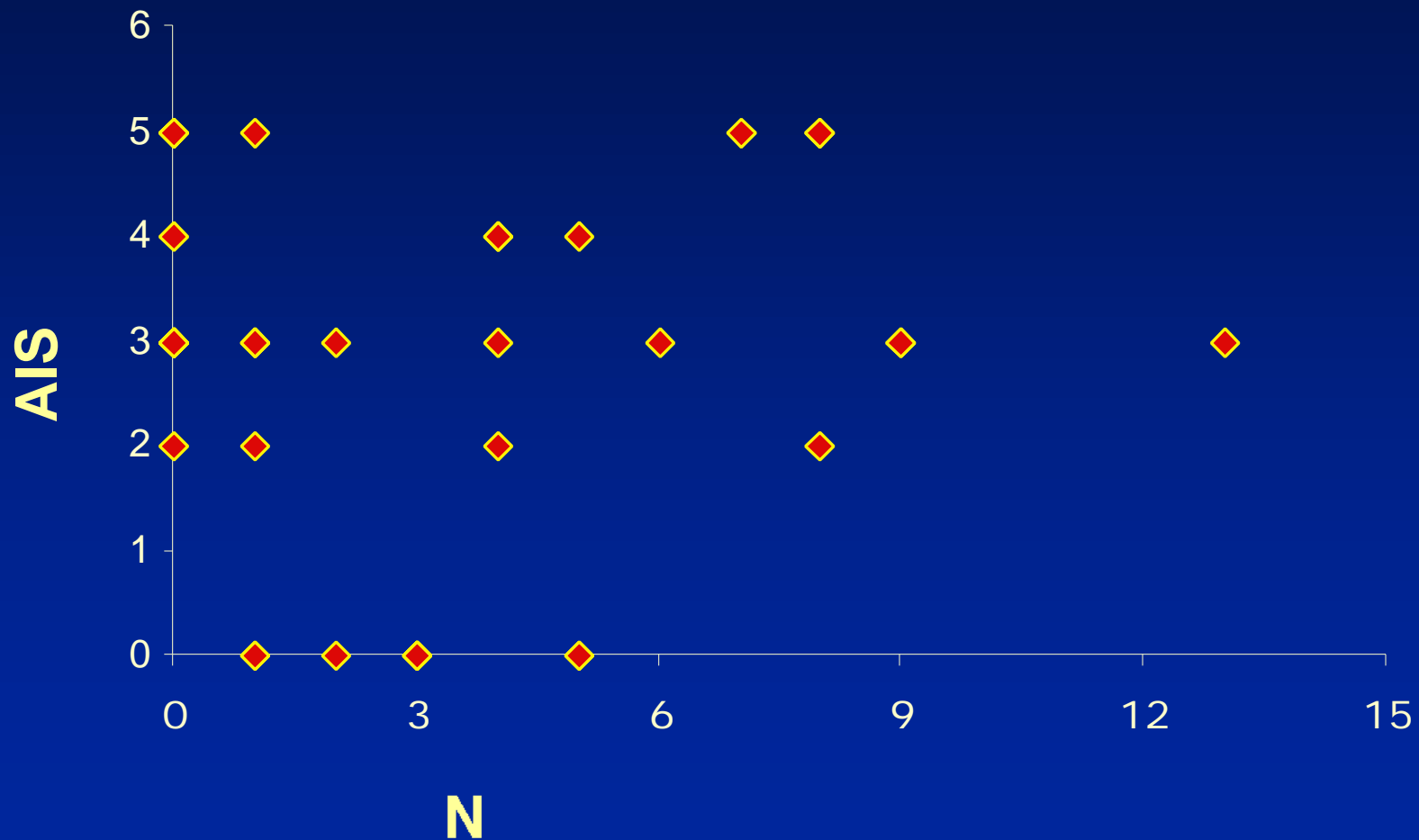
Occupants With S, V, and S+V Injuries in Near-Side Impacts



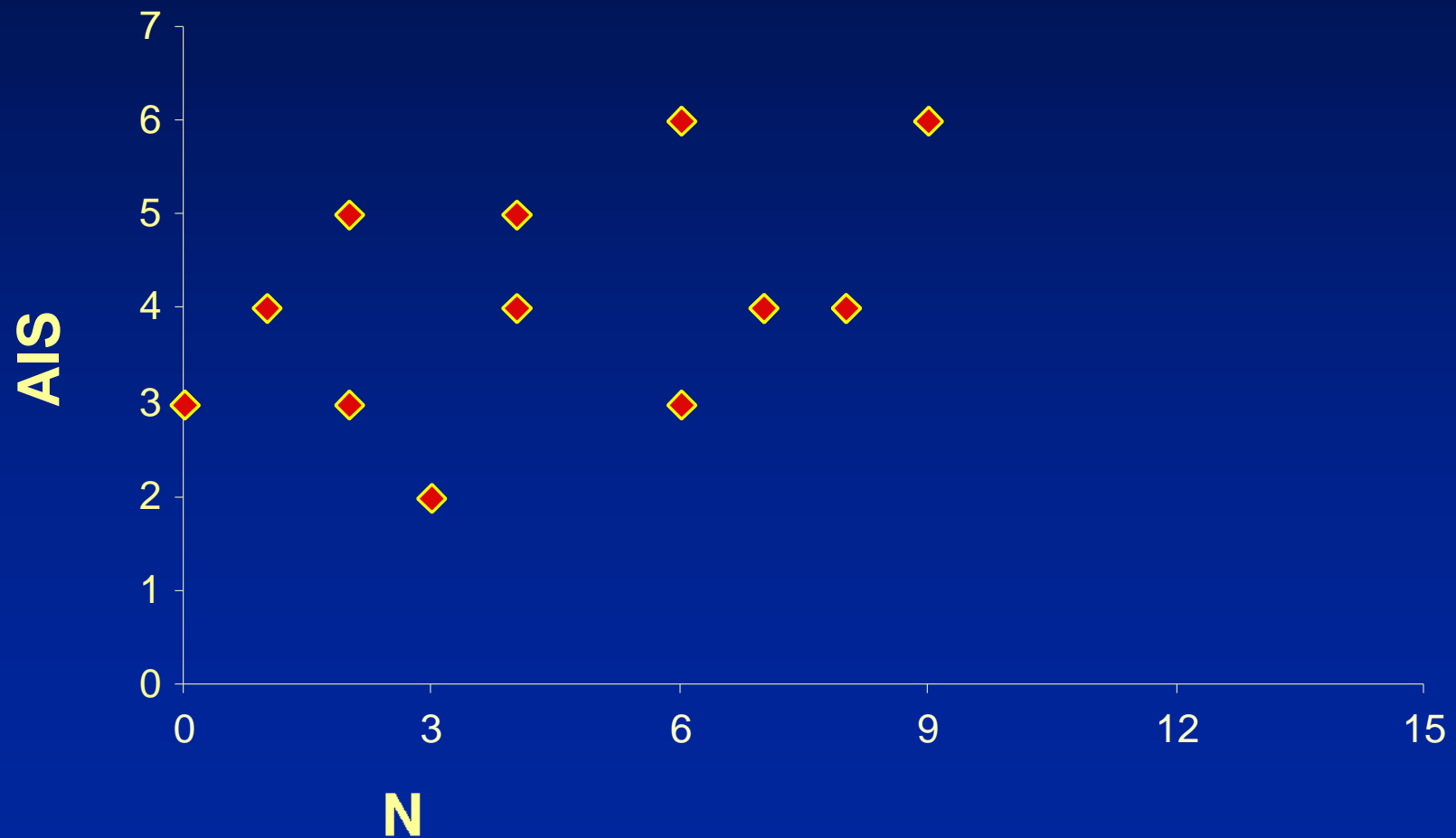
Patterns of Skeletal and Visceral Injuries in Frontal and Near-Side Impacts

Relationships Between #s of Rib Fractures and Non-Skeletal Injury Severity

Highest Visceral AIS versus Number of Rib Fractures in FRONTAL Impacts



Highest Visceral AIS versus Number of Rib Fractures in Near-Side Impacts



Observations

INJURY VS. NO INJURY

- Belt, airbags, and belts + airbags are offering excellent protection to the thorax/abdomens of occupants involved in moderate to severe frontal impacts.

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- There are no obvious differences in the distributions of key variables such as age, gender, and crash severity for occupants with and without thorax/abdomen injuries in frontal crashes, although newer model vehicles and SUVs & pickup trucks comprise a greater percent of the no-injury cases than the with-injury cases.

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- Occupants involved in near-side impacts are much more likely to sustain serious and life-threatening thorax/abdomen injuries than occupants involved in frontal impacts.

Observations

SKELETAL VS. VISCERAL

- Only 1/4 of the thorax/abdomen injured occupants involved in frontal crashes sustained skeletal injuries without visceral injuries.

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SKELETAL VS. VISCERAL

- Only 1/4 of the thorax/abdomen injured occupants involved in frontal crashes sustained skeletal injuries without visceral injuries.
- Visceral injuries without skeletal injuries tend to occur in younger occupants.
- There is little correlation between the number of rib fractures and the highest visceral AIS injury.
- Life-threatening visceral injuries (i.e., vessel tears) may occur in near-side impacts in the absence of skeletal fractures on the struck side of the ribcage.

Observations

LOCATIONS OF RIB FRACTURES

- In contrast to results obtained in cadaver testing (Crandall et al. AAMA 2000, Kallieris, ESV 1998; Yoganandan et al. 1991 - 1998), rib fractures are most common at the lateral aspects of the ribcage for belted occupants in frontal crashes.

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- In contrast to results obtained in cadaver testing (Crandall et al. AAMA 2000, Kallieris, ESV 1998; Yoganandan et al. 1991 - 1998), rib fractures are most common at the lateral aspects of the ribcage for belted occupants in frontal crashes.
- Rib fractures for airbag-only restrained occupants in frontal crashes may occur anywhere on the circumference of the ribcage, but commonly occur posteriorly, especially on the outboard side - these fractures are generally attributed to sources other than the airbag.

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LOCATIONS OF RIB FRACTURES

- In contrast to results obtained in cadaver testing (Crandall et al. AAMA 2000, Kallieris, ESV 1998; Yoganandan et al. 1991 - 1998), rib fractures are most common at the lateral aspects of the ribcage for belted occupants in frontal crashes.
- Rib fractures for airbag-only restrained occupants in frontal crashes may occur anywhere on the circumference of the ribcage, but commonly occur posteriorly, especially on the outboard side - these fractures are generally attributed to sources other than the airbag.
- In near-side impacts, rib fractures occur primarily laterally and posteriorly on the struck side.

Recommendations

- CIREN centers should increase efforts to obtain and document specific locations of skeletal and visceral injuries.

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- The CIREN database should allow for accurate coding of skeletal and visceral injury locations.
- Additional pattern analysis of CIREN thorax/abdomen skeletal and visceral injury data should be conducted using data from multiple centers.
- Results of these analysis should be of value to developing improved injury criteria, to analyzing injury causation in crashes, and to diagnosing thorax/abdomen injuries of crash victims.